Non-Ferrous Metals I

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3663048: Hybrid Formulation Impact on Copper Corrosion
Arturo Carranza, David Edwards, Joseph Remias, Huifang Shao, Brian Sears, Jose Montenegro, Afton Chemical Corporation, Richmond, VA

Hybrid vehicles represent a significant part of the engine oil market and will continue to expand on the coming years. Corrosion, especially under cold climate conditions, has been identified as a key challenge for electrified vehicles due to intrinsic water retention. Understanding limitations and advantages of lubricant components under harsh operating conditions is crucial to developing robust formulations. The present work describes corrosion kinetics for key components in the automotive industry in the presence and absence of water. The approach allows for corrosion mechanism categorization and modeling under various performance conditions. In addition, the method has been used to evaluate several hybrid lubricants out in the market.

8:30 - 9 am
3663820: Stability of Emulsions for Aluminum Hot Rolling
Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

Aluminum is usually hot rolled thanks to an oil-in-water emulsion with typical oil concentration being 1-10%. The emulsion stability relies on chemical (surfactant type and concentration) and mechanical (stirring) characteristics. In this paper, different stability measurement techniques have been compared: static destabilization kinetics by light retrodiffusion, oil droplet size by laser diffraction, coulter counter and emulsion stability index (ESI). Lab experiments on "clean" emulsions showed that the different techniques converged on global stability trends, with specific indications on emulsion health with each device. Lab results were then used to understand emulsions behaviors on production hot rolling mills. It has been possible to evaluate the impact of the different following phenomena occurring on an emulsion in use: strong shearing through spray nozzles, surfactant build-up, contribution of the metallic particles on emulsion stability.

9 - 9:30 am
3668803: Investigation of Lubricity Performance of Self Emulsifying Lubricant for Aluminum MWF by Using Molecular Modelling.
Ronald Hoogendoorn, Ramesh Navaratnam, Patech Fine Chemical, Dublin, OH

To reduce energy consumption the use of light weighted metals is growing. Hence machining of these materials and the required lubricity performance of MWF lubricants become more important. In this presentation, a molecular model focusing on Self-Emulsifying Lubricant (SEL) structure and its adsorption/spreading ability on the metal surface is developed, and validated the performance in aluminum application by tapping torque test and block on ring test. Based on this model, physical/chemical characteristics of the SEL in solution and interaction phenomena on metal surface have been studied. By comparing the test results of block copolymer PAG with various self-emulsifying esters (SEE), we show how SEL structure and related solvent properties can impact lubricity performance of aluminum metalworking fluids in different application tests.

9:30 - 10 am

3668860: An Experimental Method for Comparing Relative Tendencies of Cold Rolling Base Oils to Generate VOCs
James Anglin, Allegheny Petroleum Products Co., Monroeville, PA

The tendency for a cold rolling base oil to evaporate under process conditions can impact plant emissions as well as fire risk, worker hygiene, and process consistency. Certain properties of candidate cold rolling oils can provide a qualitative indication of whether their use may impact existing stack emissions levels. These properties can include vapor pressure, flash point, and distillation curve information. In this work, an improved measure of the expected tendency to evaporate was sought using actual evaporation rates under temperature conditions relevant to coolant systems. This information may be helpful in obtaining regulatory approval for proposed base oil changes.

10 - 10:30 am - Break

10:30 - 11 am
3669196: Nuclear Magnetic Resonance Spectroscopy as a Useful Tool for Estimating Formulation Variations of Emulsions Used for Aluminum Hot Rolling
Josef Leimhofer, AMAG rolling GmbH, Ranshofen, Austria

For aluminum hot rolling, emulsions with different compositions (e.g. fatty acid based and fatty acid free) are in use. With respect to composition, the emulsifier system is investigated, as well as the addition of fatty acid to an originally fatty acid free emulsion system, using, among others, nuclear magnetic resonance spectroscopy.
The work will show the results of corresponding measurements and how they are used as additional information to judge the applicability of the modified emulsion formulations.

11 - 11:30 am
3669414: In Aluminum Rolling What Are the Effects on Surface Quality
Andrea Knopp, Constellium, Ravenswood, WV

Last year we laid out what Tramp Oils are and how they can effect Rolling Fluids. This year I want to take a much deeper dive and focus on the effects that Tramp Oils have on surface quality. This will focus on both Hot Rolling and Cold Rolling systems.

11:30 am - 12 pm
3644040: Field Performance Simulation Pilot Mill Testing for Aluminum Hot Rolling Oils
Thomas Oleksiak, Ze Feng, Bas Smeulders, Michiel van Breemen, Pablo Bakermans, Wim Filemon, Zhiming Ma, Kai Ye, Peter DeBruyne, Wenbing Jiang, Quaker Houghton, Oswego, IL

Simulating the field performance of aluminum hot rolling oils is a challenging process. It is not only difficult to simulate a contact where metal reduction is taken in a rolling/sliding contact but also the high temperatures and roll coating formation are further complicating factors. Using a pilot rolling mill, a field simulation process has been developed and tested. Performance factors include mill parameters as well as an evaluation of anodized quality. Key oil and emulsion parameters will also be reported. This field simulation was used in the final development stages of a low acid product and will be used further in new aluminum hot rolling platform developments. Comparative data of the low acid product versus traditional soap-based chemistry will be presented.

Lubrication Fundamentals VII - Measurement

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3669357: The Measurement of Tribofilm Formation Using a Combination of Visible and Infrared Light
Matthew Smeeth, Clive Hamer, PCS Instruments, London, United Kingdom

In order to study the “tribofilm” formation, rigs such as the MTM (mini-traction machine) are run under mixed sliding speed conditions, allowing antiwear additive reactions to occur. Each optical interferometry image captured is analyzed to correlate the Red, Green and Blue colors to lubricant film thickness. A unique combination of RGB pixel values will correspond to a known film thickness. Beyond a certain film thickness value however, the colors will start to repeat which can give ambiguous results. In order to overcome this, measurements have been made which combine visible light with longer wavelength infrared light, effectively giving 4 unique “colours” and therefore a far wider measurement range. The paper will discuss the details of the new technique and show how it can be applied to measured relatively thick tribofilms films formed by a variety of additives which were previously indeterminate, thereby extending the range of this powerful technique.

8:30 - 9 am
3664409: In-Situ Chemical Characterization of Degraded Lubricant During Rubbing
Bastien Bolle, Janet Wong, Pavlos Aleiferis, Imperial College London, London, United Kingdom

A Lubricant is subjected to chemical changes during its operational life. These variations affect lubricant properties and may have serious consequences its effectiveness. To investigate the link between the chemical changes and performance of a lubricant, a MTM (Mini Traction Machine) test rig with in-situ Raman spectroscopy is used to examine tribofilm formation of various chemicals during rubbing. This allows chemistry and friction of the tribofilm to be correlated directly. Specifically, the effects of shear (by varying slide-roll ratio), temperature, gas environment on degradation of base fluids will be presented. Base fluids of interest include iso-octane, hexadecane and PAO.

9 - 9:30 am
3647567: Study of Tribological Contact Condition Using the Non-Linear Behaviour of Longitudinal Ultrasonic Waves
Saeid Taghizadeh, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

When the amplitude of incident ultrasonic waves is small (linear ultrasound), waves reflected from a contact contain information about the contact state. However, it is not possible with a single measurement to distinguish between reflection from an oil film and a solid contact -i.e., whether it is mixed or hydrodynamic lubrication. This limitation can be improved using a high-power ultrasonic wave (non-linear ultrasound). The reflected wave from the contact is distorted, and higher order frequencies are generated in the wave. It this study, a new reflection coefficient (second order reflection coefficient) using non-linear ultrasound, is presented. This has a different response to a dry contact and a lubricated film. By combining both linear reflection coefficient and second order reflection coefficient they can be to independently give the lubricant thickness and tribological contact conditions.

9:30 - 10 am
3669413: The Effect of Surface Structure on Friction and Film Thickness in Running-In Phase
Petr Sperka, Ivan Krupka, Martin Hartl, Brno University of Technology, Brno, Czechia

Film thickness thinning and decrease of lubricant viscosities is related with considerable decrease of surface roughness to maintain full film separation. The optimal surface roughness is affected by wear

processes that take place during running-in phase. In this phase several non trivial processes are combined, i.e. surface roughness influences elastohyrodynamic lubrication, surface features are deformed elastically or plastically, and surface structure is modified by wear. This study combines in-site and ex-site measurements of film thickness, friction, and surface topography for several various structures. Results show how different parameters of surface structures influence running-in process and stable friction. The effect of real roughness on film thickness is presented.

10 - 10:30 am - Break

10:30 - 11 am
3688903: Traction, Stribeck and Scuffing Characteristics of Lubricants in Rolling-sliding Contacts Using Twin Disc
Debdutt Patro, Sravan Josyula, Harish Prasanna, Deepak Halenahally Veeregowda, Ducom Instruments, Bangalore, India

Rolling sliding contacts are subjected to high contact pressures (1.5 to 4 GPa) and slip ratios (0 to 100%). Traction, Stribeck and scuffing characteristics of lubricants affect the efficiency and durability of the machine elements. In this work, Twin Disc Roller on Roller was used to measure the traction and scuffing performance of a commercial 20W-50 oil. After the traction tests, a peak in the coefficient of friction was observed with 40% slip with an increase in lubricant temperature. In the Stribeck tests, a transition from EHD to boundary lubrication was observed. Scuffing tests were run in co-rotation and contra-rotation. The load was increased until sharp increases in friction or vibration occurred. Post-test microscopy indicated severe material transfer and surface damage.
Such test methods can effectively and quickly screen different base oil and additive chemistries in a repeatable manner and enable development of lubricants for electric vehicles and high speed railways.

11 - 11:30 am
3646586: Novel Test Methods for Electric Transmission Fluid Development
Yungwan Kwak, Afton Chemical, Richmond, VA

Vehicle electrification is a key technology to improve vehicle fuel efficiency, reduce greenhouse gas emission, and create a healthier environment. Drivetrain lubricants in this application are different than those of conventional transmissions. Thus, an urgency to develop various new test methods exists, so that robust fluid performance under real-world operating conditions can be assured. This presentation will discuss various new tests developed for electric transmission fluid (ETF) development. Discussion topics will include 1) understanding a fluids' cooling performance, and electric motor/power electronics; 2) copper corrosion under various operating conditions, including non-electrified and electrified conditions; 3) circuit board and low voltage connector tests; 4) magnet wire compatibility, with a focus on both breakdown voltage and partial discharge; 5) plastic insulation material compatibility; and 6) electrical property of ETF under application conditions.

11:30 am - 12 pm
3665915: Structural Analysis of PFPE and MAC Space Lubricants
Gordon Jones, David Douce, Waters Corporation, Wilmslow, Cheshire, United Kingdom; Michael Buttery, Rachel Bingley, European Space Tribology Laboratory, Warrington, United Kingdom

Quadrupole Mass spectrometry combined with Atmospheric Solids Analysis Probe (ASAP-MS) is demonstrated as a technique for the structural characterization of two space lubricants, a perfluoropolyether (PFPE) and a multiply alkylated cyclopentane (MAC). Full scan negative ion mass spectra of the PFPE samples were dominated by sequences of oligomeric alkoxy fragment ions, each retaining one terminal end group of the polymeric chain. The fragmentation patterns were characterized by cleavage at the C-O bonds. Thermally aged PFPE lubricants showed similar characteristics to fresh oil but with more fragmentation. Analysis of the MAC samples, highlighted, a major peak at m/z 911.7amu in positive and m/z 942.3amu in negative ion modes, likely relating to the tris (2-octyldodecyl)-cyclopentane. Fragmentation was evident in both spectra aligning with CH3, CH2 and CH homologous series. Thermally aged MAC lubricant showed similar characteristics to the fresh oil, again with more fragmentation.

Condition Monitoring III

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3669144: Condition Monitoring Method for Oxidation of Biodegradable Hydraulic Oils
Tomomi Honda, University of Fukui, Fukui, Japan

Recently, it is required to use biodegradable oil from the viewpoint of global environmental problems. On construction machines, online sensing systems have been developed, and some construction machines are beginning to use fluid property sensors. However, there are few reports on the degradation diagnosis of biodegradable hydraulic fluid using fluid property sensors. In this study, we aimed to improve the diagnostic accuracy by investigating their relationships with the parameters of the color analysis sensor and the fluid property sensor. We made oxidized biodegradable oils using the RPVOT without water and catalyst and measured color parameters, physical properties, and TAN using these sensors. As a result, it was suggested that using a combination of color analysis and fluid property sensor, we can detect the early stage of oxidation and indirectly know the value of TAN from the dielectric constant.

8:30 - 9 am
3669267: Ageing and Reconditioning of Gearbox Oils: The Tribological Perspective
Arnaud Ruellan, Aldara Naveira-Suarez, SKF Group, Gothenburg, Sweden

Imagine the benefits of being able to continuously or regularly recondition oils restoring the tribological performance levels required for a given application. A new reconditioning technology combining chemical and advanced filtering techniques has been developed to remove contaminants including submicron particles from oils, hence removing catalysts for oil degradation, and thereby extending the oil life. In this study, the tribological performance of the reconditioned industrial gearboxes have been compared to that of the fresh and used oil collected from the field by using specific tribological screening methods in combination with standard chemical analyses. While the main objective is to make sure that key lubricating properties are not altered during the reconditioning process, results also underline the importance of understanding the negative and/or positive effects of oil ageing and of defining the concept of oil life depending on the application.

9 - 9:30 am
3669316: By Lubes
Antonio Lopes, Axel Royal LLC, Panama City, Panamá, Pana, Panama

A perfect relationship between lubricants, surgically considering the secondary effects of friction, wear, and temperature. It is no longer acceptable to go beyond the industry's requirements, of the OEM of equipment, without considering the responsibility of CAPEX, which is in the hands of maintenance managers.
There is no longer saying that people without specific abilities will become lubricators as in the past. Instead, maintenance must now focus on standards under responsible, trained, and skilled technical leadership in managing resources. How much does an hour of the machine down? For unexpected maintenance? Why not invest in predictive maintenance? I will inform you how to protect your equipment in simple steps, find a better cost-benefit ratio, and create an effective cost reduction, which means COSTDOWN. Ask me how?
9:30 - 10 am
3669322: A Novel Technique Combining Automated Liquid Particle Counting and Elemental

Analysis by ICP-OES
Keith Schomburg, PerkinElmer, Magnolia, TX

Particle counting is used by in-service lubricant analysis laboratories as a standard test to determine contamination levels of in-service lubricants. Valuable information regarding the health of the equipment can be gained by knowing the size distribution of particles within the fluid. This information is often related to potential wear and life expectations of the equipment. Recently, a new instrumental technique has been developed which integrates particle counting with wear metals testing by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES). For this new technique, a small volume of lubricant is diluted with solvent for normal wear metals analysis by ICP-OES. As the diluted sample is transferred to the ICP it is tested by an optical particle counting device in-line to the sample introduction system. This new integrated technique can be performed in 45 seconds per sample and provides both particle size distribution data and wear metals analyses into one analysis.

10 - 10:30 am - **Break**

10:30 - 11 am
3670334: Improved Oil Condition Monitoring of Industrial Lubricating Oils
Ruediger Krethe, OilDoc GmbH, Brannenburg, Germany

Oil oxidation is the most important process in oil aging for almost all industrial lubricants. New application areas and requirements for much longer oil drain intervals lead to a strong increase in the use of fully saturated, synthetic oils. Typical test patterns like viscosity, acid content and IR oxidation are not sufficient for a reliable oil condition monitoring of synthetic oils particularly in large oil reservoirs. Therefore, the monitoring of additive depletion and of the formation of oxidation-related by-products becomes more important. The paper demonstrates the principle and application of new methods in oil condition monitoring. 1. New lab methods of Oil Condition Monitoring, 1.1 Oxidation Index, .2 Additive depletion, 1.3 Deposit potential testing 4 Examples A number of examples form different application areas demonstrate the value of the new test methods and how to interpret the test results in the context of the conventional tests.

11 - 11:30 am
3678842: A Novel Homogenizing ICP Sample Introduction Approach
Steven Twining, Elemental Scientific, Inc., Navasota, TX

Running oil samples for elemental content by Inductively Coupled Plasma Optical Emission Spectroscopy or, ICP-OES is often challenging as samples struggle to remain well mixed. Even recent use of mechanical stir mechanisms often fail to keep samples homogenized due to a time lag between the stir process and analysis. This talk covers technology that enables laboratories to analyze samples of varying viscosities reliably using a new homogenization process that occurs immediately before each sample analysis. The result is an elemental analysis that’s closer to one that is representative of the actual lubricant as it flows through the machine compartment it was designed to lubricate. This enables laboratories to provide an accurate elemental picture of the wear, additive, and potential ingress elemental content.

11:30 am - 12 pm
3671792: Determination of Nitrite Levels in Engine Coolant by UV/Vis Spectroscopy
Nicholas Lancaster, PerkinElmer, High Wycombe, Buckinghamshire, United Kingdom

Literature reports that the second major cause of engine and equipment failure behind lubricant failure, is that of the coolant. Formulations of engine coolant (also known as antifreeze) consist of glycol, water, and an additive package. These formulations of coolant can differ by their additive chemistry, but the function of such chemicals is common –to deter the deterioration of the surface of wet cylinder lines. Nitrite (NO_2^-) is a common additive to coolant formulations used to preventing pitting by creating an oxide patina on the liner exterior. The nitrite is consumed as it is in use however and as such requires frequent testing by either paper test strip or laboratory analysis. The paper test strip is a manual analysis and can prove

unreliable. Using EPA method 354.1 as a template we can develop a method to accurately determine nitrite levels in glycol based aqueous engine coolant using UV/Vis Spectroscopy alongside an autosampler for rapid sample preparation and analysis.

7E Southern Hemisphere V

Nanotribology IV

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3649988: Evaluating Fuel Lubricant Additives – Relating the Nano to the Macro Scales
David Burgess, Zhenyu Jason Zhang, Peter Fryer, University of Birmingham, Birmingham, United Kingdom; Jacqueline Reid, Ian McRobbie, Innospec, Ellesmere Port, United Kingdom

Organic friction modifiers (OFMs) as fuel lubricant additives have been researched in great detail since their discovery in the early 1920's. Industrially fuel lubricity is evaluated using rapid bench-top testing most notably the high frequency reciprocating rig (HFRR) being an ISO standard method. Some research questions the ability of these methods to evaluate, distinguish and better understand OFMs in fuel. We use a wide variety of nanotribological techniques (AFM, QCM and Langmuir trough) to develop molecular understanding of the factors affecting the OFM performance and then relating to them to more rapid macroscale testing to allow new ways of viewing the way we analyze and evaluate how OFMs work. We see there two main factors for OFM functionality: The equilibrium performance and the kinetics factors of the binding adsorption processes. By understanding ways of improving both of these factors, OFMs can be tailored to the needs of the operational environment.

8:30 - 9 am
3645202: Nanoscale Frictional Behavior on Electrochemically Corroded Hard Carbon-Based Film: Roles of Surface Topography and Vapor Environment
Chen Xiao, Fiona Elam, Feng-Chun Hsia, Bart Weber, Steve Franklin, Advanced Research Center for Nanolithography, Amsterdam, Netherlands

Hard carbon-based film has attracted extensive attention as a protective coating for tribological applications including the employment in humid and charged environments because of its superior wear resistance and chemical inertness. Here, the electrochemical properties, surface chemistry, and frictional responses (in dry air, humid air, and isopropanol vapor (IPA) environments) of two carbon-based films with different surface roughness were investigated. XPS and Raman results show evidence for surface oxidation during the electrochemical corrosion, which results in no changes to the nanoscale topography but improves surface wettability. The friction force increases upon corrosion in water vapor conditions due to the intensifying capillary condensation of the relatively more hydrophilic surface, but decreases in IPA condition due to the boundary lubrication. In addition, rougher surface results in a lower friction force in water vapor conditions, but higher friction in IPA condition.

9 - 9:30 am
3646121: In Situ Observation of ZDDP Tribofilm Growth by Changing Surface Morphology Using Atomic Force Microscopy
Kaisei Sato, Graduate School of Tokyo University of Science, Tokyo, Japan; Seiya Watanabe, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan

ZDDP is known to form reaction film between sliding surfaces and protect adhesion wear. However, there are few reports about in situ observation of tribofilm formation due to difficulty in investigating the formation process in nano-scale. Recently, Gosvami et al. observed the growth process of the ZDDP

tribofilm using atomic force microscopy (AFM). In addition, they confirmed that the ZDDP formation started at scratch marks. From these backgrounds, we considered that the growing amount of tribofilm could be controlled by changing the surface morphology. In this experiment, we confirmed that a rough surface promoted the growth of tribofilm compared to a smooth surface. In addition, the formation process showed that the tribofilm grew from each asperity of tribofilm-selves and the rough surface formed more shape tribofilm. Based on the above, we consider that the promotion of tribofilm growth is due to increased contact pressure by decreasing the radius of single asperities.

9:30 - 10 am
3646517: Sintered Tribofilm Growth as a Function of Steel Substrate Microstructure
Steven Thrush, US Army DEVCOM GVSC, Warren, MI

Recent experiments confirmed that zirconia nanoparticles dispersed in oil have the ability to generate robust tribofilms in steel/oil boundary lubrication tests through nanoparticle surface capture followed by particle accumulation and tribological sintering. However, the ability of the nanoparticle to generate a tribofilm has a strong dependence on its material properties relative to the counterfaces of the tribocontact. Heat treatment of steel counterfaces allowed for control of hardness while their elastic properties remained relatively constant. More uniform tribofilm growth was found on harder steel counterfaces. In contrast, softer surfaces grew patch-like tribofilms correlative to harder steel grains. Thus, the tribofilm growth was steel microstructure dependent, isolated to the grains with sufficient hardness to permit localized tribosintering. Tribofilm growth and morphology were characterized as a function of steel microstructure.

10 - 10:30 am - **Break**

10:30 - 11 am
3678885: A Study on the Formation and Characterization of Tribofilms Derived from Inorganic Nanoparticles in Boundary Lubricated Sliding Contact
Kora Farokhzadeh, Steve Papanicolaou, Bruker Nano Surfaces, San Jose, CA; Ian Armstrong, Bruker, Santa Barbara, CA; Steve Shaffer, Shaffer Tribology Consulting, San Jose, CA

Inorganic nanoparticles are introduced as lubricant additives to maintain low friction in boundary lubricated sliding contact due to their ability to enhance load bearing capacity and thermal stability. To implement model lubricants on large scale and optimize performance it is essential to understand the mechanisms of lubrication and tribofilm formation in mixed or boundary lubrication regimes. In this study, MoS_2 and CeO_2 nanoparticles were suspended in base (PAO) and formulated (10W-30) oils and tested under pin-on-flat reciprocating conditions in self-mated bearing steel surfaces. The incidence and thickness of tribofilms generated during experiments were characterized using AFM and white light interferometry. The findings were used to understand how the intrinsic properties of the nanoparticles affect tribofilm formation, friction behavior and interfacial phenomena under extreme pressure conditions.

11 - 11:30 am
3653280: Tribology of Plasma Functionalized $CaCO_3$ Nanoparticles in the Presence of Thiophosphate Antiwear Additives.
Pranesh Aswath, Kimaya Vyavhare, UTA-Materials Science and Engineering, Arlington, TX; Richard Timmons, The University of Texas at Arlington, Arlington, TX; Ali Erdemir, Texas A&M University, College Station, TX

The surface modified $CaCO_3$ nanoparticles were synthesized through plasma enhanced chemical vapor deposition (PECVD). Oil formulations were prepared with functionalized $CaCO_3$ nanoparticles in combination with ashless dialkyl dithiophosphate (DDP) and zinc dialkyl dithiophosphate (ZDDP). Tribological test results indicate synergistic interaction of functionalized $CaCO_3$ nanoparticles with ZDDP and DDP providing enhanced friction and wear performance under boundary lubrication. Improved wear protection by functionalized $CaCO_3$BM nanoparticles under boundary lubrication was attributed to the formation of Calcium and Boron-rich 50-80 nm thick tribofilms on the worn surface. XANES results indicate that the functionalized $CaCO_3$ nanoparticles interact with ZDDP and DDP and form tribofilms

either by tribochemical reactions or metal cation supply. These results indicate plasma functionalized $CaCO_3$ nano-additives can reduce concentration of harmful P-based additives in the automotive lubricants.

11:30 am - 12 pm
3647872: Presentation TBD
Pranjal Nautiyal, Robert Carpick, University of Pennsylvania, Philadelphia, PA

Abstract Coming Soon

7G — Northern Hemisphere A2

Environmentally Friendly Fluids III

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3658516: Blending with Sustainable Base Oils and Other Oils to Achieve Biodegradable Finished Lubricants – A Little Bit Goes a Long Way!
Michael Woodfall, Biosynthetic Technologies, Indianapolis, IN

Biodegradability of finished lubricants is attainable for all! Even a small percentage of biobased, sustainable base oils can transform your formulation from inherently biodegradable to readily biodegradable. This 30 minute session will be a MUST for anybody looking to develop environmentally acceptable lubricants through blending with sustainable biobased products. The speaker will provide examples of finished formulations covering: grease, hydraulic fluid and gear oils.

8:30 - 9 am
3664256: Science & Technology of Next-Generation Fuels & Lubricant Additives
Prem Pal, REDA Chemicals, Edmonton, Alberta, Canada

Fuels and lubricants are an essential part of our life. With time, our understanding of producing more efficient fuels and lubricants for complex and advanced machines has constantly been improving. In order to achieve increased performance, efficiency while still meeting the environmental regulations several types of chemical additives are mixed into base fuels and lubricants. Additives can make up from 0.1 to 30 volume percent of the finished product, depending upon the target application of the lubricant product. Additives are expensive chemicals, and creating the proper mix or formulation of additives is a complicated science. This presentation will walk us thru the basic chemistry and engineering of some of the additives, especially the next-generation environment-friendly ones, and how they are revolutionizing the fuels and lubricants industry.

9 - 9:30 am
3658810: HX-1-Approved Biobased Hydraulic Fluids
Mark Miller, Biosynthetic Technologies, Indianapolis, IN

The market for vegetable oil based hydraulic fluids has grown because of relative advantages that these fluids have, when compared with other fluid types. However many biobased hydraulic fluids do not comply with some requirements. A new category of biobased hydraulic fluids are NSF H-1 certified and comply with the European EcoLabel and USDA's BioPreferred® Program. These food-grade hydraulic fluids serve as a drop-in replacement to conventional mineral-based hydraulic fluids and offer superior lubricity, improved operational performance and lower overall environmental impact, and deliver extreme pressure and wear resistance characteristics along with biodegradability. This method of blending, will

provide hydraulic fluids that will help food companies meet environmental sustainability objectives as well as reduce the bio-hazard risks associated with accidental spills due to non-toxicity (> 100 ppm as per the OECD 201, 202, and 203) & high biodegradability (>75% by the OECD 301B).

9:30 - 10 am
3664549: Breaking the Viscosity Ceiling: Development of Readily Biodegradable High Viscosity EAL Synthetic base fluids.
Ramesh Navaratnam, Patech Fine Chemical, Dublin, OH

As the performance demand for new Environmentally Acceptable Lubricants (EAL) grows, formulators are driven to develop high viscosity Synthetic lubricants. However, highly complex molecules are either not readily biodegradable or unable to meet key performance criteria are like hydrolytic stability, hydrocarbon base oil miscibility, anti-wear/lubricity, rubber compatibility, and oxidation stability. Some of these requirements are conflicting in general perception, such as biodegradability and hydrolysis resistance. This presentation will show how such limitations were overcome, and readily biodegradable saturated complex esters with the viscosity of 1,000 and 3,000 cSt @40C were developed. In addition, we also show the estimation results of application characteristics by using unique model based on molecular perspective.

10 - 10:30 am - **Break**

10:30 - 11 am
3658832: Innovations and Regulations For Biobased and Sustainable Lubricants and Additives
Mark Miller, Biosynthetic Technologies, Indianapolis, IN

Some of the greatest innovations in the lubricants market have been in the development and utilization of high performance, environmentally acceptable lubricants (EALs). This presentation focuses on the innovations, features, benefits, strengths, and limitation of the different types of EALs and additives. It explores classification of base fluids and additives as well as the requirements of finished lubricants. It compares the performance of conventional petroleum products and biolubricants. In addition, the different definitions of environmental acceptability are explored as well as the regulatory driving forces and the requirements for each. The considerations for choosing the type of EAL that is most applicable to specific applications will be explained and finally, the best maintenance practices to ensure long fluid and equipment life will be discussed.

11 - 11:30 am
3668828: Feasibility of Bio-Lubricants Under Mixed Lubrication Conditions
Sam Davison, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

A bespoke test rig which pushes journal bearings into mixed lubrication regimes has been designed and biodegradable lubricants have been put to the test under these extreme conditions. It's estimated that 50% of all of the lubricants produced are lost into the environment. Biodegradable lubricants are a necessary technology to protect the environment for future generations and also have demonstrated excellent lubricity and potential to reduce energy losses. Legislation also dictates the use of biodegradable lubricants, the highest profile being the vessel general permit VGP legislation for lubricants used in the marine sector. Confidence in biodegradable lubricants is relatively low and they're blamed for a rise in bearing failures particularly in marine stern tubes. To date, experimental comparison of the performance of lubricants has been limited to hydrodynamic testing which shows little difference between the lubricants. This work aims to fill that gap.

7H — Northern Hemisphere A3

Synthetic Lubricants and Hydraulics I

Session Chair: Ryan Fenton, BASF Corporation, Tarrytown, NY
Session Vice Chair: Lauren Huffman, Dow Chemical, Midland, MI

8 - 8:30 am
3668716: High VI Industrial Lubricants and Their Impact on Equipment Efficiency
Ricardo Gomes, Frank-Olaf Maehling, Thorsten Bartels, Lucas Voigt, Phil Hutchinson, Evonik Oil Additives, Horsham, PA

Hydraulics and pneumatics are used throughout the industry for a large variety of end uses, e.g. hydraulic excavators. Most of these applications become more and more demanding with increasing operating pressure, smaller fluid volumes and higher specific workloads. A significant amount of power is consumed by these applications. Besides robustness and reliability, energy efficiency is an aspect of increasing importance. Many end users are confronted with the need to reduce Total Costs of Ownership and like to consider every option to improve productivity and efficiency of their equipment. This is closely linked to the increased focus on sustainability. The paper will discuss the demand for more efficient operation of fluid power applications and will show how shear-stable, high-VI hydraulic fluids can improve the equipment efficiency by several percent compared to incumbent monograde fluids.

8:30 - 9 am
3668356: Modeling the Effect of Polymer Structure and Chemistry on Viscosity Index, Thickening Efficiency, and Traction Coefficient
Pawan Panwar, Ashlie Martini, University of California, Merced, Merced, CA; Emily Schweissinger, Stefan Maier, Stefan Hilf, Sofia Sirak, Evonik Industries, Hanau, Germany

The chemistry and structure of base oil and polymer additive molecules in lubricants directly affect viscosity index (VI), thickening efficiency (TE), and traction coefficient (TC). However, the relationship between molecular properties and these key performance metrics is still not fully understood, inhibiting design of fluids with potentially improved performance. This study used molecular dynamics simulations to identify structure-property-function relationships for lubricants of similar viscosity consisting of different polymers having chemistries consistent with commercially available products. Then, simulation calculated VI, TE, and TC were validated by experimental measurements. The differences in VI, TE, and TC between the fluids were investigated by simulation-calculated multiple structural properties of the polymers. Finally, simulations were used to develop simple models to rapidly predict these properties which can ultimately guide design of new lubricants or additives.

9 - 9:30 am
3644828: Quantifying Wet Brake Chatter Using Accelerometers
Michael Botkin, Caroline Mueller, Southwest Research Institute, San Antonio, TX

Wet brakes are common in off-road equipment and other high-torque applications where high levels of heat must be dispersed. Under the right conditions, wet brakes are susceptible to brake chatter caused by a stick-slip action that can result in noise and excessive vibration. Current brake chatter tests quantify brake chatter as audible noise or variations measured in torque at the brake. In the method described in this paper, an accelerometer is used to detect brake chatter and quantify its severity in an off-road axle. A Fourier Transform on the data collected during a brake engagement is used to observe the resonant frequency of the axle system. The summed area under this region of the curve is used to measure the energy of the system at the resonant frequency, and the sum is compared to a threshold value that discriminates quiet engagements from noisy engagements. This process reliably identifies brake chatter and provides a quantitative measure of its severity.

9:30 - 10 am
3648474: VI Improvers for Energy Efficient Compressor Oils
Justin Kontra, Frank-Olaf Maehling, Lucas Voigt, Bin Xu, Evonik Oil Additives, Horsham, PA

Air compressors and pneumatic systems are responsible for a significant fraction of the overall industrial power demand. These systems are required to be robust and reliable. Energy efficiency is an aspect of increasing importance and linked to the increased focus on sustainability. Approaches to improve the efficiency of positive displacement compressors have focused mostly on design, while the development of high VI fluids to boost performance remains largely underutilized. Ideal lubricants protect high wear surfaces, enhance sealing at compression interfaces, and improve overall volumetric efficiency. To measure the impact of high VI compressor oils – lubricants with synthetic high viscosity PAMA base stocks and shear stable viscosity index improvers were benchmarked against market general compressor oils, in both pneumatic and refrigerant compressors. Fluids with VIs above 165 consistently demonstrated significant efficiency gains, while maintaining oxidative and thermal stability.

10 - 10:30 am - Break

10:30 - 11 am
3670950: Metallocene Catalysts on Ethylene Propylene Oligomer as Synthetic Base Oil and Viscosity Modifier
Dianta Ginting, DL Chemical, Daejeon , Yusung Gu , Republic of Korea

The properties of Synthetic based oil design to more superior compared to a mineral base oil, such as better low-temperature performance, better oxidation stability, better viscosity index, and extended life. The advantages of metallocene catalysts are high activity, narrow MWD, wide product range, uniform molecular weight distribution, good physical performance, and good electrical properties. The advantages of metallocene catalysts are high activity, narrow MWD, wide product range, uniform molecular weight distribution, good physical performance, and good electrical properties Ethylene. Based on the metallocene catalyst, the Ethylene Propylene oligomer has good properties such as less hazy, good low-temperature properties, good shear stability, good chemical stability, good oxidation stability, and easy handling. This experiment will explores ethylene-propylene oligomer as base oil and as a viscosity modifier

11 - 11:30 am
3667495: High Viscosity Index Tractor Hydraulic Fluids that Meet Multiple OEM Specifications
Durga Prasad Chalasani, Ricardo Gomes, Justin Langston, Frank-Olaf Maehling, Evonik Oil Additives, Horsham, PA

Tractor Hydraulic Fluids (THF) are multi-purpose fluids designed to transmit power and to lubricate and protect transmissions, differentials, hydraulic components, wet brakes, among other functions. THF specifications are set by OEM's and some of the popular and commonly used specifications include those from John Deere, Massey Fergusson, ZF, CNH, among others. High Viscosity Index THF's that can meet the specifications of multiple OEM's in a single fluid offer potential benefits to both lubricant marketers and end users, such as- simplifying inventory management, reducing errors in application, lower maintenance costs and equipment interoperability. This presentation will discuss the development of such single fluid THF formulations and review the lab and performance test data.

11:30 am - 12 pm
3670662: Development of a New Fuel Efficient, Shear Stable Axle Lubricant to Meet New US GHG Requirements
Arjun Goyal, BASF Corporation, Florham Park, NJ

EPA and NHSTA on behalf of DOT have enacted rules to establish the reduction of GHG of new on-road heavy duty vehicles. This paper describes the development of a new lower viscosity, shear stable, synthetic heavy-duty axle lubricant. The lubricant consists of a unique combination of synthetic base oil and proprietary viscosity improver which results in superior low-and-high temperature properties with excellent extended-length shear stability. The new lubricant meets the SAE J2360 and leading axle manufacturers extended oil drain specification requirements. The new axle lubricant also shows fuel savings of 0.79% and axle temperature reduction of 5.2C over a fuel efficient SAE 75W-90 axle lubricant. Using EPA estimates, the use of new fuel efficient lubricant is estimated to save over $300 and reduce

carbon dioxide (CO2) by over 200 kg per truck per year. Field tests are progressing in various long-haul fleets with one fleet has accumulated over 225,000 no-drain miles with no issues

7I Northern Hemisphere A4

Fluid Film Bearings II

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3668648: Identification of the Dynamic Force and Torque Characteristic of Annular Gaps
Maximilian Kuhr, Peter Pelz, Technische Universität Darmstadt, Darmstadt, Hessen, Germany

The presented work investigates the rotordynamic force and torque characteristic of annular gaps such as seals and journal bearings. Although the dynamic influence of both components is known, the influence of the tilting and moment coefficients has been neglected in almost all experimental investigations. In order to close this knowledge gap, a worldwide unique test rig is operated at the Chair of Fluid Systems at the Technische Universität Darmstadt. Essentially consisting of two radial magnetic bearings for force measurement, excitation and displacement of the rotor, the test rig covers the relevant parameter range for turbulent and laminar flow in narrow annular gaps. In an extensive parameter study, the influence of the annulus length, a modified Reynolds number, the flow rate, the pre-swirl, and the centre of rotation on the force and torque characteristic is investigated. Furthermore, the experimental results are compared to a new and general simulation method.

8:30 - 9 am
3663212: A Bayesian Approach for Shaft Centre Localization in Journal Bearings
Christopher Lindley, Scott Beamish, Rob Dwyer-Joyce, Nikolaos Dervilis, Keith Worden, The University of Sheffield, Sheffield, United Kingdom

Ultrasonic techniques work well for online measuring of circumferential oil film thickness profile in journal bearings. However, attempts to model the oil film thickness from these measurements usually rely on deterministic approaches, which assume the observations to be true with absolute certainty. Unaccounted uncertainties of the oil film thickness may lead to a cascade of inaccurate predictions for subsequent calculations of the hydrodynamic parameters. In the present work, a probabilistic framework is proposed, and likelihood maps are constructed to display the probable location of the shaft centre given the bearing rotational speed and applied static load. The results offer the possibility to visualize the confidence of the predictions and allow the true location to be found in an area of high probability within the bearing's bore.

9 - 9:30 am
3642865: Measuring Oil Films in Dynamically Loaded Journal Bearings
Scott Beamish, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

This paper describes the design of a journal bearing test platform capable of high accuracy film thickness measurements via permanently embedded ultrasonic transducers. A bespoke hydraulic loading system with programmable valves allows the application of dynamic loads with set loading patterns, including the simulation of loading patterns found in real components. Tests under a range of rotation speeds, temperatures and lubricant types have allowed the detailed analysis of film thickness response to rapidly changing loads.
Unlike conventional methods, the ultrasonic technique offers a non-invasive direct measurement of the shaft-bearing interface, thus enabling the study of phenomena such as cavitation, bearing deformation and oil pressure effects. Results have been compared against eddy current sensors, a theoretical model, and numerical techniques. This work focuses on the rig design, refining the technique, validation and how

the system is being applied to current industrial problems.

9:30 - 10 am
3668808: CAPM – A New Model for Design of Media-Lubricated Journal Bearings Under Turbulent and Laminar Flow Conditions
Robin Robrecht, Peter Pelz, Technische Universität Darmstadt, Darmstadt, Hessen, Germany

Media-lubricated journal bearings use the process fluid of the pump as lubricant. The process fluids often have low viscosity, i.e. water or some hydrocarbons. The operation conditions of media-lubricated journal bearings are characterized by large eccentricity, significant axial flow, and moderate Reynolds numbers. The flow is mostly turbulent but can be laminar in some cases. Under these conditions, the use of typical models based on Reynolds equation or Bulk Flow Theory often leads to unreliable prediction of leakage and dynamic forces on the rotor. For this reason, the new Clearance Averaged Pressure Model (CAPM) was developed and validated for turbulent flow.
In this presentation, the CAPM is introduced and results are compared with a Reynolds equation model and CFD data for laminar operation conditions with consideration of inlet pressure losses due to the axial flow.

10 - 10:30 am - **Break**

10:30 - 11 am
3668712: Simulation of the Dynamic Force and Torque Characteristics of Annular Gaps - Rotordynamic Relevance of the Tilt and Moment Coefficients
Maximilian Kuhr, Peter Pelz, Technische Universität Darmstadt, Darmstadt, Hessen, Germany

In the present work, the relevance of the rotordynamic force and torque characteristic of annular gaps such as seals and journal bearings is investigated. Although the dynamic influence of both components is known, the influence of the tilting and moment coefficients is generally neglected below an overall threshold defined by the ratio of the annular gap length to the rotor radius $L/R < 1.5$. The derivation of this threshold neglects the operating point of the annulus and any other geometric or operational parameters. To overcome this, a new and generalized simulation method is presented. The method is then used to calculate the rotordynamic force and torque coefficients over a wide range of parameters, leading to a much sharper formulation whether the tilt and moment coefficients can be neglected or must be taken into account.

11 - 11:30 am
3669020: Hybrid Fluid Film Bearings for Liquid Rocket Engine Turbopumps: Test Rig Development and Performance Prediction
Keun Ryu, Kyuman Kim, Howon Yi, Chanwoo Lee, Hyunsung Jung, Homin Lim, Seki Sin, Seungho Choi, Junwon Heo, Minsoo Wee, Hanyang University, Ansan, Gyeonggi-do, Republic of Korea

Turbopumps in reusable liquid rocket engines require compact fluid film bearings to support the large thrust and radial loads at high shaft speeds. Hybrid bearings offer significantly enhanced durability with low friction and wear while providing accurate rotor positioning as well as large load and static stiffness characteristics even working with low viscosity liquids. The current work develops multiple test rigs for measurements of the static and dynamic load performance of cryogenic fluid film bearings and identification of bearing force coefficients. Experimentally validated predictive bearing models significantly reduce time and expenses in further developments of cryogenic hybrid bearings. The work conducted is a stepping stone in a concerted effort aiming towards developing a complete bearing technology integrating cryogenic hybrid bearings for the design, prototyping, and troubleshooting of envisioned reusable rocket engine turbopumps for next-generation propulsion systems.

11:30 am - 12 pm
3639364: Non-Newtonian Couple-Stress Squeeze Film Behaviour Between Oscillating Anisotropic Porous Circular Discs with Sealed Boundary
Benyebka Bou-Saïd, INSA Lyon, Villeurbanne , France; Mustapha Lahmar, Bilal Boussaha, Guelma

University, Guelma, Algeria

We investigate theoretically the non-Newtonian couple stress squeeze film behavior between oscillating circular discs on the basis of V. K. Stokes micro-continuum theory. The lubricant squeezed out between parallel porous plates is supposed to be a concentrated suspension. The effective viscosity is determined by using the Krieger-Dougherty model. For low frequency and amplitude of sinusoidal squeezing the governing equations including the modified Reynolds equation coupled with the modified Darcy's equation are derived and solved numerically. The slip velocity at the porous-fluid interface is directly evaluated considering laminar and isothermal squeezing flow. The couple stress effects on the squeeze film characteristics are analyzed through the dimensionless couple stress parameter considering sealed and unsealed boundary of the porous disc.

7J Northern Hemisphere E1

Materials Tribology III

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3645630: Experimental and Numerical Study of the Friction of Carbon Fiber Tows
Noel Brunetiere, Kiran Bhantrakuppe Narayanappa, Olga Smerdova, CNRS, Universite Poiters, ISAE-ENSMA, Chasseneuil du Poitou, France

Carbon fibers tows are used as reinforcement material in composite elements. To ensure mechanical integrity of the composite structure it is important to ensure a good positioning of the carbon fibers in the mold during the manufacturing process. The positioning of the carbon fiber tows strongly depends on the friction with the mold.
In the present work, the friction between a carbon tow placed on a cylindrical pin rubbing on a rotating glass disk is experimentally studied in dry and resin lubricated conditions on a dedicated tribometer. The tests are performed for different loading levels and sliding speeds. The results are compared to numerical simulations considering contact mechanics and lubrication. The tows are modeled using a simple elastic foundation approach coupled with the Reynolds equation when the resin flow is considered.

8:30 - 9 am
3663350: Comparison of Scuffing and Wear of Hard Materials in Four Low-Lubricity Fuels
Stephen Berkebile, Monica Ferrera, Nikhil Murthy, US DEVCOM ARL, Aberdeen Proving Ground, MD; Kelly Jacques, Maddox Dockins, Euan Cairns, Aditya Ayyagari, Diana Berman, Samir Aouadi, Andrey Voevodin, The University of North Texas, Denton, TX; Auezhan Amanov, Ruslan Karimbaev, Sun Moon University, Asan, Republic of Korea

High-pressure common-rail fuel delivery systems operate under harsh conditions due to internal lubrication with the fuel. Low viscosity of fuels, variations in fuel chemistry, and tight mechanical tolerances tend to promote high wear and scuffing that can lead to premature failure of components. Hard coatings have the potential to mitigate these failure in fuel-lubricated mechanical interfaces and increase operational life. Using several tribological methods and interface conditions, we will present and compare the wear and scuffing resistance of around 20 hard coatings in F-24 jet fuel, ethanol, decane and dodecane. The coatings fall into categories of tungsten carbides, diamond-like carbons, nitrides, and oxides with various thicknesses and surface treatments. Of the 20 coatings, at least three demonstrated lower wear in most fuels with respect to hardened AISI 52100 steel. However, we demonstrate that scuffing resistance must be considered for a full assessment of suitability.

9 - 9:30 am

3668923: Investigation of the Evolution in Chemistry and Physical Steel Contacts During the Scuffing Process
Kelly Jacques, Andrey Voevodin, Samir Aouadi, Thomas Scharf, Diana Berman, University of North Texas, Denton, TX; Rose Pesce-Rodriguez, Stephen Berkebile, US DEVCOM ARL, Aberdeen, MD

Fuel pump materials must resist wear when lubricated upon operation in hydrocarbons under conditions of dynamic fluid pressure and flow to expand fuel compatibility. Determination of new materials to implement in such systems to protect them against scuffing is impeded without a thorough understanding of scuffing initiation on currently used hardened steel surfaces. In this work, a pin-on-flat high-frequency reciprocating tribometer was used to establish an experimental method that repeatably produces scuffing events on self-mated through-hardened AISI 52100 steel. Optical microscopy, scanning electron microscopy, energy dispersive spectroscopy, profilometry, Raman spectroscopy, and Fourier transform infrared spectroscopy were used to characterize the evolution of sliding interfaces during scuffing. Overall, it was found that the chemical composition and wear behavior of AISI 52100 steel differed greatly for surfaces subjected to scuffing and those which resisted scuffing initiation.

9:30 - 10 am
3644063: High-Throughput Investigation of a High Strength Additively Manufactured Multi-Principal Element Alloy
Morgan Jones, Irene Beyerlein, University of California Santa Barbara, Santa Barbara, CA; Nicolas Argibay, Iver Anderson, Emma White, Prashant Singh, Duane Johnson, Ames Laboratory, Ames, IA; Andrew Kustas, Frank DelRio, Ping Lu, Sandia National Laboratory, Albuquerque, NM

Multi-principal element alloys (MPEAs) show great promise for use in the power generation industry due to their high melting temperatures and strength. Additive manufacturing (AM) methods enable fabrication of compositionally graded specimens and rapid exploration of composition-dependent properties. AM was paired with scratch testing techniques to determine hardness and toughness, followed by microstructural analysis to identify deformation mechanisms. Micro-scratch and nanoindentation experiments were performed on an AM MPEA specimen, which was found to have extraordinary mechanical properties. High temperature nanoindentation showed remarkable strength and thermal stability, with negligible change in strength up to 500 C. Density-functional theory calculations showed that this system favors the formation of multiple highly-thermodynamically stable phases, corroborated by transmission electron microscopy, which also revealed evidence of highly coherent phase boundaries.

10 - 10:30 am - **Break**

10:30 - 11 am
3642145: Crystal Rotation Kinematics During Dry Sliding on High-Purity Copper
Christian Greiner, Christian Haug, Peter Gumbsch, Karlsruhe Institute of Technology, Karlsruhe, Germany; Dimtri Molodov, RWTH Aachen University, Aachen, Germany

During the tribological loading of metals, dislocation-mediated plasticity results in a variety of microstructural changes, including grain refinement or the formation of crystallographic textures. One key process involved therein is the reorientation of the crystal lattice, or crystal rotation. Our work sheds light on the early stage, fundamental mechanisms of tribologically induced lattice rotation kinematics. Using a high-purity copper bicrystal and a sapphire sphere, unlubricated, single-pass sliding tests were conducted. Electron backscatter diffraction (EBSD) performed directly on the wear track reveals a crystal rotation process around the transverse direction at the heart of tribologically induced lattice rotation, irrespective of sliding direction, grain orientation and normal load. A detailed analysis corroborates that surprisingly, changing the sliding direction merely alters the precise accommodation of crystal rotations, but not their fundamental nature.

11 - 11:30 am
3647024: Evolution of Surface Cracks Under Rolling Contact: 3D Crack Morphology and Influence of Material Composition
Chiara Bertuccioli, Amir Kadiric, Imperial College London, London, United Kingdom; Kenred Stadler, SKF,

Schweinfurt, Germany

This paper presents recent research into the evolution of surface initiated rolling contact fatigue cracks morphology in different stages of their growth. Rolling contact fatigue (RCF) tests were carried out on a triple-disc fatigue rig to generate surface cracks under controlled contact conditions. Tests were stopped before a large crack developed into a pit using vibration signal analysis. Roller test specimens of different materials were employed to investigate the effect of material composition. 3D shapes of cracks at different stages of their development were then obtained using a custom methodology employing FIB-SEM and other analytical techniques in combination with a series of software processing steps to obtain 3D crack coordinates. The results are presented to describe the evolution of crack morphology as crack length increases and to illustrate the pertinent effects of material composition.

11:30 am - 12 pm
3670524: Tribological Performance of Sliding Parts in Low Viscosity Fluids
Aditya Ayyagari, Maddox Dockins, Euan Cairns, Diana Berman, University of North Texas, Denton, TX; Stephen Berkebile, US DEVCOM ARL, Aberdeen Proving Ground, MD

Moving towards environmentally sustainable technologies, understanding the wear and friction behavior of industrial coatings in low viscosity and/or volatile fluids such ethanol, decane or kerosene has gained importance. While lubricity is largely governed by the fluid dynamics of the lubricant, the wear behavior of the contacting surfaces in presence of the low molecular weight hydrocarbons is also strongly dependent on the materials properties and formation of tribochemical compounds that can strongly influence the surface interactions. This study presents the mechanism defining the tribological properties of materials in alcohols and alkanes that is validated for several hard industrial coatings. The observations are complemented by detailed surface characterization techniques – mass spectrometry, Raman spectroscopy, and advanced electron microscopy.

7K — Northern Hemisphere E2

Metalworking Fluids III

Session Chair: TBD
Session Vice Chair: TBD

Session Starts at 8:30 am

8:30 - 9 am
3645759: Metal Working Fluids Containing Hydroxyproline Rich, Natural Proteins Have Reduced Drag Out and Provide for Cleaner Machines and Workpieces.
Eric Yezdimer, Gelita USA, Sergeant Bluff, IA; Matthias Reihmann, Gelita AG, Eberbach, Germany

Multiyear use of synthetic metal working fluids containing hydroxyproline rich, natural proteins (HRPs) in multiple machine shops have found several performance improvements, including reduced drag out and cleaner machines/workpieces. Previously it was found that HRPs form dynamic, nanometer thick, hydrophilic layers on metal surfaces that improve cooling and provide lubricity. In this work, it was determined that the addition of HRPs to semi-synthetic fluids modify the net chemical adhesion profile on steel and aluminum surfaces. The use of water and oil soluble dyes, spectrophotometry and TOC measurements allowed for surface residue quantification and demonstrated HRPs reduced the adhesion of oil emulsions to the surface. Tapping torque experiments with semi-synthetics spiked with HRPs also demonstrated improved lubricity. This indicates HRPs are not negatively impacting the oil performance during machining, but post operation can act to expel undesirable oils and cracked residues.

9 - 9:30 am

3647104: Formulating Aluminum Metal Working Fluids – Which Additives Provides Essential Benefits?
Michael Stapels, Kao Chemicals GmbH, Emmerich, Germany

The significantly increased use of Aluminum in our industry has long ceased to be a secret. Neglecting the specific requirements of this material in the development of an aluminum metalworking fluid will end up in an unsatisfying situation for all people involved. Beside standard requirements like cooling and lubrification particular emphasis has to be placed on the soap formation of aluminum coolants. Another important point is to avoid the highly undesired staining of the Aluminum during machining. Key to meet all these requirements is the selection of an appropriate emulsifier chemistry. One of the most promising chemistries are ether carboxylates as - in the right combination - they are able to master the balancing act between emulsion stability as well as foam- and soap-control. Additionally they provide especially in combination with a proper amine chemistry excellent stain prevention.

9:30 - 10 am
3651204: Post Machining Cleaning – How to Pick the Right Surfactant For the Job
Ashley Milton, Stephanie Cole, Clariant, Mount Holly, NC

With the hundreds of available surfactants on the market to incorporate into a metal cleaning formulation, the task of picking the correct surfactant can be daunting. Determining whether your formulation requires emulsification or rejection of foreign oil is critical for selecting the proper surfactant in a cleaning formulation. Understanding surfactant performance with various soil types, metal types and pH stability will help the end-user achieve their desired cleanliness. The backbone of the surfactant chemistry will determine the functionality of the surfactant and its application performance. This paper will define trends associated with different surfactant chemistries and how to apply this theory to developing a cleaning formulation.

10 - 10:30 am - **Break**

10:30 - 11 am
3667154: Polyglycol as Performance Wear Lubricant and Synergism with Extreme Pressure Additives on Net Oil Metalworking Fluid
Eduardo Lima, FASB - Philosophy and Sciences College, São Paulo, Brazil

To create a more robust scientific information from previous studies that considers known factors that affects wear, which brings negative aspects on metalworking process, potential damages on metal parts, unwanted wear on relative expensive tools, or debilities to create adequate and precision measures on metal parts, demands effective additive development against wear. Consequences of metal-to-metal contact is possible to be prevented by adding adequate chemistries that form a protective film between surfaces, either by physical adsorption or even by a chemical reaction. This study presents performance results exploring more from Oil Soluble Polyglycol as synthetic performance Wear Lubricant Additive proposal and covering more on synergism with Typical Extreme Pressure Additives Study on Typical Net Oil Metalworking Fluid, creating relation between: additive molecular weight relation, bubbles release, oxidation, viscosity, and fundamental extreme pressure/ low wear.

11 - 11:30 am
3669361: How Did You Come Up With That? A Comparison Study of the Different Innovation Methods Between Large Corporations and Small & Medium Sized Enterprises (SME).
E Jon Schnellbacher, Formulas & Solutions, LLC, Allen Park, MI

Metalworking fluid formulation traditionally happened in small & medium sized enterprises although recently though mergers and acquisitions has become common in larger corporations. This presentation discusses how the R&D strategies may be applied to companies according to available resources. There is a basic structure difference between large corporations with greater resources and differentiation and small to medium size enterprise (SME's) with less than 500 employees. Do they create products the same way? The North American Chemical Manufacturers Best Practices Study (NACM-BPS) indicates

otherwise. SME companies have smaller R&D staffs that fill different roles including both technical service and product development. Furthermore, they also tend to have fewer resources limiting their ability to do more innovative and radical innovation. This presentation discusses challenges and strategies between different size companies adopting the best innovation practices.

7L — Northern Hemisphere E3

Tribology of Biomaterials I

Session Chair: Alison Dunn, University of Illinois, Urbana, IL
Session Vice Chair: Kylie Van Meter, Florida State University, Tallahassee, FL

8 - 8:30 am
3669024: Tribology of Soft Contacts Lubricated by Particulate Suspensions
Christopher Serfass, Catherine Hill, Elias Kerstein, Yug Saraswat, Lilian Hsiao, North Carolina State University, Raleigh, NC; Shravan Pradeep, University of Pennsylvania, Philadelphia, PA

The presence of suspended solid particles in consumer products such as foods and cosmetics greatly influences texture perception. This has led to increased interest in understanding the tribology of these systems. To investigate the influence of particles in lubricated tribopairs, we prepare lubricants that comprise suspensions of poly(methyl methacrylate) microparticles of various sizes ($0.4\ \mu m \leq 2a \leq 1.5\ \mu m$) and volume fractions ($0.05 \leq \varphi \leq 0.50$) in squalene and perform velocity sweep tests using a ball-on-three-plates geometry. We observe a reduction of friction in the boundary regime, the appearance of a φ-dependent plateau in the mixed regime, and a φ-dependent rate of increase in friction in the elastohydrodynamic regime. To account for the nonlinear increase in viscosity as φ increases, we use steady shear rheological testing to characterize the suspension viscosity. Our overall aim is to create a framework linking tribological and rheological behavior in colloidal suspensions.

8:30 - 9 am
3669423: Interfacial Wear of Soft Hydrogels Due to Repeated High-Speed Cavitation Events
Alexander McGhee, Jin Yang, Elizabeth Bremer, Christian Franck, University of Wisconsin-Madison, Madison, WI

Inertial microcavitation, the formation and collapse of micron to millimeter-sized bubbles, is a widely found phenomenon across engineering and life sciences. Examples include cancer ablation therapies using focused ultrasound histotripsy procedures or spontaneous formation in ballistic, blast, or directed energy events. Within these various applications, a fundamental understanding of the finite deformation behavior of the soft material (e.g., tissue) during cavitation is paramount for quantitative predictions of material failure, damage, and cellular injury for living tissues.
This study has resulted in the full-field measurement of the temporal evolution of subsurface deformation, strain, stress, pressure, and volumetric expansion of the surrounding material during repeated cavitation events at a fluid-hydrogel interface.

9 - 9:30 am
3669352: Patterned Elastomeric Materials in Lubricated Tribology
Lilian Hsiao, Yunhu Peng, Christopher Serfass, North Carolina State University, Raleigh, NC

The interfacial film thickness between two patterned surfaces strongly influence the elastohydrodynamic lubrication (EHL) friction coefficient because of its contribution to the shear and normal forces in lubrication analysis. We use a tribology accessory on a stress-controlled rheometer to examine how an interfacial fluid film, comprising a mixture of water and glycerol, separates two solid surfaces in tribological sliding conditions. Poly(dimethyl siloxane) (PDMS) materials and hydrogels are patterned using photolithography and replica molding. We combine Reynolds' equations with linear elasticity to model the

tribological behavior of soft materials, including that of robotic and human fingertips. Softer patterns bend more easily during applied deformation, which consequently decreases the EHL friction. Our results collectively show that the liquid film is a key parameter in the tribology of soft materials, and furthermore enables the design of friction in realistic environments.

9:30 - 10 am
3669442: In Situ Observation of Interface Between a Glass Syringe and Elastomer Stopper for Low Temperature Storage of Biologics
Kylie Van Meter, Pont de Claix, France; Brandon Krick, Florida State University, Tallahassee, FL; Nestor Rodriguez, Eloise Perrin, BD Medical-Pharmaceutical Systems; Avinash Tiwari, Bo Persson, Peter Grubber Institute, FZ Julich, Julich, Germany

Biologics like mRNA-based vaccines for COVID and some cell therapies require storage at temperatures of - 80°C to keep the therapeutics stable and maintain dose potency. During the freeze-thaw cycle of the vaccine, the components of a prefilled-syringe (rubber stopper, lubricant, glass body, liquid) undergo thermal, mechanical, and physical changes that can affect the integrity of the internal sealing of the syringe and the vaccine itself. In this study, freeze-and-thaw experiments were performed to study the behavior of a system comprised of a glass syringe with a butyl rubber, silicone oil lubricated stopper filled with deionized water. The contact and position of the rubber stopper and glass syringe interface was observed with in situ adaptive optics. The results revealed a complex behavior of the prefilled system during freeze-and-thaw caused by the confined and non-uniform crystallization of water and the thermal transitions occurring at the glass-lubricant-elastomer interface.

10 - 10:30 am - **Break**

10:30 - 11 am
3669232: Tribological Performance of Additive Manufactured Partial Implants Sliding Against Articular Cartilage Assessed Using In Vitro Experiments
Manel Rodriguez Ripoll, Timea Varadi, Rosa Eder, Markus Kronberger, Friedrich Franek, AC2T research GmbH, Wiener Neustadt, Austria; Christoph Bauer, Stefan Nehrer, Danube University Krems, Krems, Austria

Hemiarthroplasty, a medical procedure consisting in the replacement of half of the affected joint has emerged as a less aggressive alternative to full replacement surgery. However, it has been widely observed that the remaining native cartilage left after hemiarthroplasty experiences accelerated wear when in contact against partial implants. The aim of this work is to evaluate the potential of additive manufactured materials using Laser Metal Deposition as partial implants. The additive manufactured materials are investigated under reciprocating sliding motion against bovine osteochondral plugs in controlled electrochemical conditions using a floating cell with a three-electrode set up coupled to a microtribometer. The results are benchmarked against CoCrMo in terms of friction, tribocorrosion performance and metal release. Further, the impact of implant material on cartilage damage is assessed based on the metabolic activity of chondrocytes and the expression of catabolic genes.

11 - 11:30 am
3669398: Evolution-Structure-Property Relationships of Tissues Drive Functionality in Slicing and Grinding Dentitions
Tomas Grejtak, Tomas Babuska, Lehigh University, Bethlehem, PA; Tyler Hunt, Stephen Kuhn-Hendricks, Gregory Erickson, Florida State University, Tallahassee, FL; Soumya Varma, Deeksha Kodangal, Siddhartha Pathak, Iowa State University, Ames, IA; Mark Norell, American Museum of Natural History, New York, NY; Santiago Lazarte, Brandon Krick, Florida A&M University–Florida State University, Tallahassee, FL; Manish Jain, Swiss Federal Laboratory for Materials Science and Technology, Thun, Switzerland

Teeth are biomechanical marvels that evolved over millions of years through natural selection to be functional and damage tolerant as they are crucial to the survival of the organism. Multifunctional grinding dentitions of grazers are composed of several tissues with varying mechanical properties that act together

to withstand high surface stresses over millions of loading cycles to obtain nutrients from plants covered with hard and wear promoting particles. Dental enamel is the most remarkable tissue of all. Although it is composed of ~ 95 % of brittle hydroxyapatite crystallites, it exhibits exceptional strength and toughness, properties that are typically mutually exclusive. This work aims to understand the role of individual tissues and their properties on the functional grinding dentition of mammals and the relationship between the hierarchical designs of the enamel microstructures and their exceptional properties at different scales through multiscale mechanical characterization.

7M — Northern Hemisphere E4

Rolling Element Bearings VII

Session Chair: TBD
Session Vice Chair: TBD

8 - 8:30 am
3666064: Modelling Geometrical Raceway Deviations of Roller Bearings in Multi-Body Simulation
Patrick Wingertszahn, Onur Atalay, Bernd Sauer, TU Kaiserslautern, Kaiserslautern, Germany

Even high-precision machine elements such as rolling bearings are subject to geometric deviations from the nominal shape from the manufacturing process. But components can also be deformed during assembly or operation. In the case of rolling bearings, the adjacent construction is often the cause and affects the internal geometry of the bearings. Shaft, housing and thus the bearing rings can deform due to the load situation, resulting in unwanted vibrations. In this contribution, a multi-body simulation model is used to investigate the influence of deviated internal geometries on bearing kinematics, bearing load and life. Therefore, mathematical approaches are presented that allow a consideration of roundness deviations in contact calculation. Their application is shown on the basis of some use cases. The method should provide a better understanding of the bearing vibration behavior and its causes.

8:30 - 9 am
3641287: Analysis of an Angular Contact Ball Bearing with Flexible Cage
Karine Petuya, Daniel Nelias, Univ Lyon, INSA Lyon, CNRS, LaMCoS, Villeurbanne, Rhône, France; Alexandre Leblanc, Artois University, Béthune, Pas-de-Calais, France

Aeronautical industry is currently developing ball bearings with cages made of lighter but softer materials. Such high-speed rolling element bearings experience cage deformation and stress concentration due to ball-to-pocket impacts. These are produced during acceleration and deceleration phases, and also during cruise when operating with combined thrust and radial load. However, few dynamic ball bearing models consider global and local cage elasticity, especially in 3D. This study aims at continuing Leblanc and Nelias' four contact-point quasi-static model by implementing either a rigid or an elastic cage. Besides, the system is transposed in dynamics to consider accelerations, ball-to-pocket contacts, lubrication, friction, and damping. For various ball bearing operating conditions, cage local and global deformations and cage center motion are analyzed. Particular attention is paid to critical operations as when radial-to-axial load ratio approaches one.

9 - 9:30 am
3643444: Planet Bearing Performance Analysis Focused on Potential Cage Stress and Roller Sliding Damage.
Travis Shive, SKF USA Inc, Lansdale, PA

Planetary gear designs are being utilized in electric drivetrain vehicles. Due to increased demand on speed and power in such gearboxes, it is beneficial to understand the resulting performance of planetary bearings in the gear system. Analytical tools are useful to study system designs and bearing performance especially when examining the areas of cage stress and possible skidding damage on the raceway contacts. Using internal software, cage design can be analyzed and modified to provide a further robust structure. This will be documented through various cage design comparison to represent how these cages will exhibit different stresses given the specified design. Secondary to the cage, raceway contacts will be reviewed to show areas where consideration should be taken to avoid skidding damage.

9:30 - 10 am
3640401: Minimum Energy Hypothesis in Quasi-Static Equilibrium Solutions for Angular Contact Ball Bearings
Pradeep Gupta, PKG Inc, Clifton Park, NY

The commonly used quasi-static model for angular contact bearings is enhanced by coupling the contact mechanics and bearing kinematic analyses with traction behavior in ball-to-race contacts. The points of pure rolling in the contacts are determined by minimizing the frictional dissipations based on a prescribed elastohydrodynamic traction model. Predictions of the enhanced model are in close agreement with those obtained by much more sophisticated dynamic analysis based on integration of classical differential equations of motion of bearing elements. A standalone software, containing the enhanced quasi-static model, is made freely available at www.PradeepKGuptaInc.com/AdoreQS.html. Full article: STLE Tribology Transactions, 2020, vol 63(6), 1051-1066.

10 - 10:30 am - Break

10:30 - 11 am
3667790: Simulation of Noise and Vibration of Systems with Real Rolling Bearings
Hannes Grillenberger, Schaeffler Technologies, Herzogenaurach, Germany

Noise and vibration (NVH) is becoming a more emphasized performance criteria not only for single components like rolling bearings, but also for complex systems like drive trains or gearboxes. For life and friction assessment of these systems ideal component geometries are typically used and sufficient for the design. For NVH, tolerances of the components and their interaction is much more important and cannot be neglected. For some issues single component simulations are sufficient to optimize the design for NVH. The interaction of components, impact on system level (i.e., perception of the customer) can only be assessed by system investigations. Due to the huge set of geometry parameters, tolerances and operating conditions, simulation is the only efficient way to the optimum design. The presentation shows the simulation approach to NVH design, optimization of tolerances and the impact on system level including the basic theory, plausiblization and validation examples.

11 am - 11:30 am
3666372: Vibration Isolation Strategy for Reducing Noise in Large Diameter Thin Section Ball Bearings
Joel Lawrence, Phil Jones, Jason Williams, Penn State Behrend, Erie, PA; Bryan Allison, SKF, Falconer, NY

Thin section ball bearings often are mounted to complicated mounting structures that may be dynamically excited resulting in undesirable structure borne noise. Dynamically isolating the ball bearing from adjacent mounting structures has shown promise in reducing displacement and acceleration levels within the assembly. A combination of closed form and finite element calculations are used to design elastomeric springs to achieve this isolation. Analytical and simulation models are used to show a greater than 90% reduction in supporting structure acceleration at the bearing excitation frequencies.

11:30 am - 12 pm
3669113: The Role of the Cage for Track Replenishment in Oscillating Rolling Element Bearings

Sebastian Wandel, Leibniz University Hannover, Hannover, Lower Saxony, Germany

Oscillating rolling element bearings are an important component in many applications such as in robotics or rotor blade bearings in wind turbines. In most cases, these bearings are grease-lubricated and thus susceptible to starvation. If, due to small oscillation angles, the inlet conditions cause the contact between the rolling elements and raceway to progressively dry out, resulting in a heavily starved contact, metal-to-metal contact can lead to an early bearing failure due to false brinelling. This paper shows that occasional re-lubrication cycles above a certain angle can effectively prevent wear initiation. The reason for this was found to be the ability of the cage to provide lubricant replenishment to the grease track on the rolling elements. With these findings, it is shown that a cage design optimized for oscillating applications can effectively prevent wear.

8A Southern Hemisphere I

Non-Ferrous Metals II

Session Chair: TBD
Session Vice Chair: TBD

1:30 - 2 pm
3651522: Structure-Performance Evaluation of Synthetic Metalworking Fluid Additives
Stephanie Cole, Tiffany Meyers, Clariant, Mount Holly, NC

Metalworking fluid chemistry is ever-evolving and changing due to the operation severity, increase in nonferrous metal production, and the need for sustainable green additives. Metalworking fluid is exposed to various conditions, and it must be able to withstand harsh conditions during manufacturing and processing of these nonferrous materials (e.g. rolling, cutting, forming, grinding). Lubricity additives can vary with shape, size, and solubility, contributing to the overall fluid performance. As improved health and safety attributes are becoming a necessity, it's essential to understand how molecular structure can impact product labeling and performance. This paper will discuss the various chemistries of additives that are compatible with a sustainable, oil-free metalworking fluid that effectively protects aluminum and, at the same time, deliver additional functionalities that help metalworking fluid formulators address today's formulation challenges.

2 - 2:30 pm
3647312: Correlating Viscosity of 2-Ethylhexyl Oleic Estolide Esters to Their Molecular Weight
Grigor Bantchev, Steven Cermak, USDA-ARS, Peoria, IL

Estolide esters, a class of lipids that are made from vegetable oil, were recently added to the market as renewable biobased lubricants. To widen their adoption as lubricants, their viscosity needs to be within tight limits. We measured the viscosity of the oleic estolide esters at different temperatures and compared the data with theoretical models. Mauro-Yue-Ellison-Gupta-Allan (MYEGA) was the best model to predict viscosity dependence on temperature and molecular weight. The models predicted well the measured viscosity data from the temperature and the average molecular weight of the estolides. These results will allow tailoring the estolide esters viscosity to specific applications by controlling the structure, allowing farm-based estolide esters to be used as engine oils, hydraulic fluids, metalworking fluids, etc.

2:30 - 3 pm
3647700: Formulating for High-Efficiency Cleaning and Protection Performance for Both Ferrous and Non-Ferrous Metal Surfaces
Clayton Cooper, ANGUS Chemical Co, Buffalo Grove, IL

Metal cleaning is an essential process used in manufacturing, metal processing and equipment maintenance. The common use of high-strength, lightweight alloys in automobiles, aerospace, electronics, food and beverage, and other industries has created opportunities and challenges for cleaner formulators to develop effective products that can clean and protect multi-metal surfaces. This presentation provides a fresh look at the performance of specialized alkanolamine chemistries used in metal cleaning formulations to provide a higher pH build that enables the reduction of other corrosion inhibitors. The multifunctionality of alkanolamines is shown to extend the operational window of metal cleaners and enable formulations to provide a broad and effective range of cleaning and protection performance for both ferrous and non-ferrous metals.

3 - 3:30 pm - **Break**

3:30 - 4 pm - **Non Ferrous Metals Business Meeting**

8B Southern Hemisphere II

Lubrication Fundamentals VIII - Rheology

Session Chair: TBD
Session Vice Chair: TBD

1:30 - 2 pm
3641504: Effect of the Architecture of Polymeric Additives on the Rheological Response of Lubricants in the Elastohydrodynamic Lubrication Regime
Eliane Gendreau, Janet Wong, Imperial College London, London, United Kingdom; Sarah Matthews, Shell Global Solutions (UK) Ltd, London, United Kingdom

Low viscosity lubricants are increasingly needed as they are key to reduce friction losses. They must however possess a sufficiently high viscosity at high temperatures to ensure good lubrication. To improve their viscosity-temperature behaviour, viscosity modifiers (VMs) are blended in. They are polymer additives of complex and diverse chemistries and molecular architectures. In this project, we study the effect of VMs on lubricant rheology with in situ and real-time experiments in the elastohydrodynamic regime. Flow profiles and viscosity maps of lubricants in ball-on-flat tribological contacts, obtained with novel time-resolved laser spectroscopy techniques, will be presented. The effect of pressure, shear and VM specificities will be examined. The link between the polymer architecture and the rheological response of the lubricant across scales will be discussed.

2 - 2:30 pm
3645217: Impact of Flexibility and Molecular Architecture on the Shear Thinning Response of Viscosity Modifier Polymers
Amran Mohamed, Janet Wong, Imperial College London, London, United Kingdom; Sarah Matthews, Shell Global Solutions, London, United Kingdom; Luca Mare, University of Oxford, Oxford, United Kingdom

Viscosity modifier (VM) additives are used to reduce a lubricant's sensitivity to temperature. As lubricants are often subjected to high shear rates in rubbing contacts, a thorough understanding of the behavior of the VMs under shear is critical. In this study, how VMs affect lubricant rheology is examined using dissipative particle dynamics (DPD) simulation. We focus on the effect of architectures and chain stiffness of polymer VMs. Linear, star and comb shaped polymers were used; while chain stiffness was varied by constraining the bending potential between adjacent bonds. Their shear thinning responses and thickening abilities are examined. The conformational changes of polymers are quantified to understand differences in their rheological properties and hence mechanisms of shear thinning. We find that the

shear thinning behaviour of the star and comb changes with flexibility, whereas the linear polymer experiences the same shear thinning behavior irrespective of chain stiffness.

2:30 - 3 pm
3649386: Principles for Designing Very High VI Fluids
Erik Willett, Jacob Scherger, Functional Products Inc., Macedonia, OH

Viscosity index or “VI” is a key parameter in lubricant design and selection. Higher VI for a given viscosity grade means less thinning of the oil with heat and less buildup of viscosity with cooling. This flatter viscosity-temperature means the lubricant can operate optimally under a wide range of conditions. “High VI” per specifications like ASTM D6158 HV was originally 140. Yet VI 140 is now typical with current technology; specifications like AGMA 9005-16 specify VI up to 240. Top tier lube for gear, hydraulics, automotive, EAL, and more will continue rely on their reported VI to differentiate products since many consumers consider VI to be an easy metric for quality and performance. What does the average formulator need to do to keep up with these demands? This work builds on the fundamentals of viscosity index improver (“VI improver”) selection and resulting tradeoffs in performance, but also presents novel insights about subtle effects of base oil selection early into a project.

3 - 3:30 pm - Break

3:30 - 4 pm
3647712: Measuring Mid-Shear Viscosity Using Tapered Bearing Simulator Viscometer for Viscosity Maps
Gwenaelle Philibert, Priyanka Desai, Sarah Remmert, Shell Global Solutions US, Houston, TX

Lowering engine oil viscosity is an established way of reducing engine friction and fuel consumption. While kinematic viscosity at 100°C and High Temperature High Shear (HTHS) viscosity at 150°C are the key parameters that define an SAE grade, viscosity variations over the full range of temperature and shear rate in an engine allow for efficient design of viscosity targets. Seeking to select oils that generate the best fuel economy for their customers, Shell has been generating full-shear flow curve viscosity maps for many years already. The current bottleneck is the measurement of viscosity in the mid-shear rate range (104-106/s) that relies on time-consuming capillary technology. The TBS instrument that is widely used at 106/s for HTHS measurements per ASTM D4683 can be modified to generate shear rates beyond the stipulated 106/s by changing speed and rotor position. This work relates to automating a TBS to facilitate data generation of mid-shear viscosities.

4 - 4:30 pm
3669336: Predicting Processability of Engine Oils by identifying the True Rheological Behavior Using Microfluidic Rheometer
Ravinder Elupula, Charles Nider, Formulaction, Piscataway, NJ

Engine oils/lubricants provide lubrication to the engine parts that are in constant motion. By lubricating the engine properly, the engine lifetime can be greatly extended, and the higher fuel economy can be realized by the consumer. However, the high temperatures and shear conditions engine oils undergo when the engine is in action cannot be determined with traditional rheometers. Knowing these rheological values for each engine oil will help manufacturers in producing the best performing products in terms of better aging, better sealing, and optimal lubrication.
A novel Microfluidic Rheometer can mimic true shear conditions of an engine to provide accurate viscosity profiles of lubricant formulations. Rheometers extrapolate the data to guesstimate the viscosities. This technology doesn’t require any extrapolation, calibration, or special setup. Viscosities are continuously monitored in real-time by visual flow acquisition methods compared to a traditional rheometer.

4:30 - 5 pm
3669484: Electromagnetic Tuning of Friction Levels in GBLM Lubricated Tribosystems: An Experimental Investigation
Maria Victoria Granja Oramas, C. Fred Higgs III, Rice University, Houston, TX

Achieving in situ control of friction levels without removing and replacing lubricant materials situated within inaccessible confines of contact constitutes a grand challenge in Tribology. Externally applied electric or magnetic fields constitute a particularly promising means to actively, reversibly, and non-invasively adjust the performance of tribosystems in real-time. Using the principles of magnetohydrodynamics, this study aims to experimentally determine the electromagnetic tunability of Gallium-based liquid metal (GBLM), by analyzing its Stribeck behavior. GBLM does not only exhibit the MHD effect but has also been proposed as a viable candidate for lubrication in extreme environments, where conventional lubricants might break down or vaporize. The Stribeck behavior of GBLM will be determined across all lubrication regimes, under the effect of external transverse magnetic fields. The implication of these results on the degree of tunability of GBLM will be presented.

8E Southern Hemisphere V

Nanotribology V

Session Chair: TBD
Session Vice Chair: TBD

1:30 - 2 pm
3646636: Sliding-induced Friction Hysteresis on Graphitic Surfaces in Solvated N-Hexadecane Layers
Prathima Nalam, Behnoosh Sattari Baboukani, SUNY University at Buffalo, Buffalo, NY; Ashutosh Pitkar, Zhijiang Ye, Miami University, Oxford, OH

Sliding-induced stick-slip behavior measured by an AFM tip on graphene and HOPG in n-hexadecane presents unique characteristics while measuring friction hysteresis and strengthening. The load-dependent friction measurements displayed higher friction during unloading compared to loading. Unlike ambient air or vacuum, the friction hysteresis occurred up to a transition load, beyond which no hysteresis behavior was observed. A strengthening of friction traces was observed independent of the slide distance but dependent on the load- and slide- history. The presence of solvation layers of n-hexadecane at the graphitic surfaces seems to contribute to the observed behaviors. MD simulations resolved the radial distributions of the carbon and hydrogen atoms in the n-hexadecane and measured the deformation of the graphene in front of the tip. The organization of n-hexadecane and the resultant interaction forces on the AFM tip during sliding enabled molecular understanding of friction behavior.

2 - 2:30 pm
3647603: Experimental Study and Numerical Modelling of Sliding Contact Wear in Nanocomposite Coatings
Zulfiqar Khan, Bournemouth University, Poole, Dorset, United Kingdom

This study involved experimental investigations of Nickel (Ni), Graphene, Zirconia (ZrO_2), Alumina (Ni/Al_2O_3) and Silicon Carbide (SiC) nanocomposite coatings. A micro-friction sliding contact bench test was employed to study the tribological performance of these coatings. Scanning Electron Microscopy (SEM) and white light interferometry were employed for surface analysis. Tribological data has been combined with surface stresses, grain size, hardness, and porosity to develop numerical models. U-shaped geometrical configuration has been employed for understanding interfacial energy distribution of coating-substrate system. This has led to the development of multidisciplinary mechanistic, mechanics and energy distribution based numerical models. Numerical solutions are in close agreement with experimental results. Comparative wear profiles of nanocomposite coatings showed that Ni-Graphene had the highest wear resistance comparing to other candidates.

2:30 - 3 pm

3668981: Understanding the Load-Dependence of Nanoscale Adhesion Using In Situ Experiments in a Transmission Electron Microscope
Tevis Jacobs, Andrew Baker, Sai Bharadwaj Vishnubhotla, University of Pittsburgh, Pittsburgh, PA; Rimei Chen, Ashlie Martini, University of California Merced, Merced, CA

Nanoscale adhesion is critical for advanced technologies, from nanoparticle catalysts to nanoscale devices. Here we discuss recent work to understand the atomic-scale physics governing nanoscale adhesion, using in situ adhesion tests performed inside of a transmission electron microscope. First, we will focus on the load-dependence of adhesion; using adhesion tests and molecular dynamics simulations to couple Angstrom-scale characterization of morphology and structure with nanonewton-scale measurements of adhesive forces. The results demonstrate the role that applied load plays in modifying the adhesive interaction, in ways not captured in traditional contact models. Second, we focus on applying this understanding of nanoscale adhesion to nanoparticles, where adhesion energy governs both stability and performance. Taken together, these results elucidate the atomic-scale interaction mechanisms at interfaces, to guide the tailoring of adhesion in nanoscale devices.

3 - 3:30 pm - **Break**

8G — Northern Hemisphere A2

Environmentally Friendly Fluids IV

Session Chair: TBD
Session Vice Chair: TBD

1:30 - 2 pm
3667627: The Performance of Diesel Engine Oil Containing Ashless Anti-Wear Additive and Detergent
Yasunori Shimizu, Moritsugu Kasai, Idemitsu Kosan Co., Ltd, Chiba, Japan

For environmental protection from air pollution, the emission from combustion engine has been severely regulated. Due to reduction of NOx gas and PM regulations, after treatment devices such as oxidation catalyst and DPF have been installed on diesel vehicle. However, it has already reported that sulphated ash, phosphorus and sulphur (SAPS) in engine oil deteriorate these performance. According to this background, the level of sulphated ash and phosphorus in engine oil standards has been reduced. From this point of view, authors have developed the novel engine oil with ashless additives instead of ZDDP and metal detergent. The developed oil showed good valve train wear protection and piston detergency in the engine tests required in JASO DH-2 specification, and also maintained good oil properties during fleet tests.

2 - 2:30 pm
3669374: Soybean-Based Cutting-Fluid Lubricants and Emulsifiers
Albert Darling, Daniel Garbark, Battelle Memorial Institute, Columbus, OH

Previously, Battelle has demonstrated the effectiveness of soybean oil derivatives in applications such as lubricants and surfactants. The experience in these technologies have allowed for development of novel classes of soybean-based cutting-fluid lubricants and emulsifiers. The tuning of fatty acid composition as well as modifications of these fatty acids are key synthetic levers by which the rise of advantageous properties such as pour points below -30C, oxidative and hydrolytic stability, and low viscosities can be achieved. With the emergence of epoxidized high oleic soybean oil as a competitively priced vegetable oil feedstock, these newly developed lubricants are projected to exhibit efficient production economics as well as the capacity for large-scale manufacturing. This presentation will demonstrate the utility and benefits of soybean oil through testing results obtained in cutting-fluid applications.

2:30 - 3 pm
3669386: Traction Coefficient Analysis in Environmentally Friendly Fluids.
Zach Hunt, VBASE Oil Company, Pendleton, SC

This presentation will cover an analysis of various Group V base oils for traction coefficient in slide-roll contact. In particular the analysis will investigate traction coefficients for ISO VG 22-68 Group V base oils comprising vegetable oil, polyol esters, oil soluble PAG, and a new hybrid PAG-Ester. The analysis will be used to present a case for quantifying lubricant derived efficiency gains in environmentally friendly fluids when compared to similar ISO VG petroleum derived products. The goal of our work is to highlight the high-performance of these Group V fluids and not just their environmental acceptability.

3 - 3:30 pm - **Break**

8H — Northern Hemisphere A3

Synthetic Lubricants and Hydraulics II

Session Chair: Ryan Fenton, BASF Corporation, Tarrytown, NY
Session Vice Chair: Lauren Huffman, Dow Chemical, Midland, MI

1:30 - 2 pm
3668709: Dynamometer Testing of Hydraulic Fluids in a Simulated Backhoe Loader Trenching Cycle
Paul Michael, Milwaukee School of Engineering, Milwaukee, WI

Hydraulic fluids were evaluated in a dynamometer simulation of a backhoe loader trenching cycle. The experimental fluids were formulated with polymers that exhibit shear-dependent viscosity loss in the critical range for axial piston pumps. Permanent viscosity loss and high shear-rate viscosities were evaluated in bench-top rheological tests. Inline viscosity and density sensors monitored changes in fluid properties during dynamometer testing. The trenching cycle was replicated by controlling pump swashplate position, outlet pressure, and speed. Torque and flow measurements were collected to evaluate pump performance. The results from the dynamic duty cycle test were compared to standard steady state measurements collected via the ISO 4409 pump performance test. Differences in the flow rate and pressure were observed. The implications for the practical testing of energy efficient hydraulic fluids are discussed.

2 - 2:30 pm
3679369: Effects of Corrosion Inhibitors on Liquid Superlubricity of Water-based Lubricants
Jannat Ahmed, Q Jane Wang, Yip-wah Chung, Northwestern University, Evanston, IL; Ning Ren, Ying Yang, Roger England, Valvoline Inc., Lexington, KY

Water-based fluids show superlubricity under certain conditions; however, corrosion of the interactive surfaces is a concern. Lubricant corrosion inhibitors help reduce or prevent corrosion of the material surfaces under lubrication. In this work, we examined three types of corrosion inhibitors and their effects on the tribological behavior of the glycerol aqueous solution with a water/glycerol weight ratio of 0.2. The experiments were conducted under the Hertzian stress up to 800 MPa and sliding speed up to 0.15 m/s. The friction results were compared with previous observations of superlubricity, by which we identified factors influencing lubricant performance and achievement of superlubricity.

2:30 - 3 pm
3668663: The Unexpected Active Behaviour of Synthetic Esters as Cobase Stocks on Resistance to Oxidation

Siegfried Lucazeau, NYCO, Paris, France

Synthetic esters are well known for their excellent thermo-oxidative stability, amongst other properties. Introducing esters as components in hydrocarbon based ashless formulation results in improved resistance to oxidation and cleanliness, as showed by oxidation and coking test results on ISO VG 32 and ISO VG 100, group II and PAO based compressor oil formulations. Whilst it is somewhat expected that introducing 5 to 20% of an oxidatively stable base fluid in a formulation proportionally reduces the effects of oxidation, things may not be that simple. Further data analysis will discuss the dilution effect generated by the introduction of a stable cobase and the possible synergistic interactions between esters and anti-oxidants. Introducing performance esters in mineral or PAO based formulations appears like a cost-effective boosting technology delivering improved resistance to oxidation and cleanliness, amongst other benefits.

3 - 3:30 pm - **Break**

3:30 - 4 pm
3647952: Liquid Amides – Novel, High Performance Base Oils
Claire Ward, Croda, Goole, United Kingdom

This paper examines a tertiary liquid amide which has been structurally designed for use as a novel, high performance Group V base oil in industrial and automotive applications. The hydrolytic and oxidative stability benefits of the new liquid amide base oil could offer enhanced product performance and lifetime over some conventional esters in challenging high temperature environments with the potential for water ingress. Both of these stability benefits are showcased in fully formulated oils for a number of industrial applications. Inherent corrosion inhibition properties of the amide and reduced oxidative degradation deposits could also help to extend the service life of this base oil and some of the mechanical components it comes into contact with. The intrinsic differences in amide and ester polarity also expand the solubility properties of this new base oil, helping to create stable formulations with some challenging components in PAO and GTL based systems.

4 - 4:30 pm - **Synthetic Lubricants and Hydraulics Business Meeting**

8I — Northern Hemisphere A4

Fluid Film Bearings III

Session Chair: TBD
Session Vice Chair: TBD

1:30 - 2 pm
3641565: Fluid Film Bearing Damage Detection from Vibration Data
John Yu, Baker Hughes, Houston, TX

Fluid film bearing damage occurred during startup after an outage on a steam turbine generator. Vibration reached over full scale of 20 mil pp (508 µm pp) at generator drive end bearing and therefore tripped the unit. The major vibration component that tripped the unit was 0.5X sub-synchronous at a level of over 20 mil pp (508 µm pp). 1X synchronous vibration excursions existed at constant speed before the trip event. Abnormal shaft centerline positions were observed. Shaft bow reached 10 mil pp (254 µm pp) at low speeds during coast-down. Bearing metal temperature reading was invalid. After an in-depth vibration data review, diagnostic conclusions and recommendations were made, followed by corrective actions. Inspection and findings confirmed bearing damage and rubs. If the vibration issue had simply be treated as rub, followed by re-start without opening the casing, further catastrophic damages would have occurred.

2 - 2:30 pm
3650184: Tribology Induced Water Pump Bearing Failure
Christopher Dellacorte, Samuel Howard, NASA, Cleveland, OH

NASA's In-Space Propulsion facility recently experienced two infant mortality water pump bearing failures with unknown origin. The failure investigation included site visits, collection and examination of physical evidence and a bearing and pump design review. The pumps are large (2000 hp) vertical turbine design machines that utilize metallic sleeve bearings cooled and lubricated by the pumped fluid (water). Detailed examination of failure surfaces combined with bearing design revealed that the failure mode was thermal seizure brought on by inadequate cooling flow. An unusual contributing factor was that the use of grease as an assembly lubricant, as opposed to a fluid like oil, appears to have exacerbated the rather than alleviated the thermal runaway by blocking water flow. Resolution of the problem was achieved through the design and installation of dedicated bearing lubrication water feed system.

2:30 - 3 pm
3641442: Performance Analysis of Multirecess Hybrid Spherical Journal Bearing Operating with Power Law Lubricant
Satish Sharma, Adesh Tomar, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

The present study investigates the influence of power law lubricant on the performance of four-pocketed hybrid spherical journal bearing system compensated with capillary restrictors. The modified Reynolds equation along with the capillary restrictor equation has been solved using Finite element method. A Matlab source code has been developed to simulate the non-Newtonian behavior of power law lubricant. The numerically simulated results reveals that the bearing performance is significantly affected by using power law lubricant. It has been observed that the non-Newtonian behavior of power law lubricant enhances the value of minimum fluid film thickness , fluid film stiffness and damping coefficients by an order of 24.07%, 12.86% and 19.68% respectively, as compared to correspondingly similar bearing operated with Newtonian lubricant. The present study is expected to be beneficial to the academia and bearing design engineers.

3 - 3:30 pm - **Break**

8J — Northern Hemisphere E1

Materials Tribology IV

Session Chair: TBD
Session Vice Chair: TBD

Session Information TBD

8L — Northern Hemisphere E3

Tribology of Biomaterials II

Session Chair: TBD
Session Vice Chair: TBD

Session Information TBD