2023 STLE Tribology Lubrication & E-Mobility Conference

November 14-15, 2023
Cleveland Marriott Downton at Key Tower
Cleveland, Ohio (USA)

Preliminary Technical Program

Updated as of Sept. 13, 2023

www.stle.org/EVconference

2023 STLE Tribology & Lubrication for E-Mobility Conference
November 13-15, 2023
Cleveland Marriott at Key Center
Cleveland, Ohio (USA)
Preliminary Program-at-a-Glance
As of 9-13-23 – Subject to Change

Monday, November 13, 2023

Networking Reception & Award Presentations – 6:00 pm–7:30 pm – Foyer

Tuesday, November 14, 2023

Speaker Breakfast – **7:00 am–7:45 am** – Erie/Superior

General Attendee Breakfast – **7:00 am–7:45 am** – Foyer

Joint Plenary Session – 8:00 am–9:00 am – Salon EFGH
Keynote Presentation:
Troy Muransky, Lead Materials Engineer, American Axle & Manufacturing
"Challenges of Selecting the Correct Electric Vehicle Driveline Fluid"

Networking Break (Exhibits & Posters) – **9:00 am–9:20 am** – Foyer

[All EV Sessions are in Salon EFGH]

3E – Electric Vehicles I
COMMERCIAL EV – **9:20 am–9:40 am**
FLUIDS – **9:40 am–10:40 am**

Refreshment Break/Poster Session – **10:40 am–11:00 am** – Foyer

[FLUIDS CONTINUED] – **11:00 am–12:00 pm**

Lunch on Your Own/Posters – **12:00 pm–1:15 pm**

4E – Electric Vehicles II
PANEL SESSION: Esters – **1:15 pm–2:30 pm**

Refreshment Break/Poster Session – **2:30 pm – 3:00 pm** – Foyer

FOAMING – **3:00 pm–4:00 pm**

Refreshment Break/Poster Session – **4:00 pm–4:20 pm** – Foyer

[FOAMING CONTINUED] – **4:20 pm–4:40 pm**

GREASE – **4:40 pm–5:20 pm**

Wednesday, November 15, 2023

General Attendee Breakfast – **7:00 am–7:45 am** – Foyer

[All EV Sessions are in Salon EFGH]

5E – Electric Vehicles III
MODELLING – **8:00 am – 9:20 am**

Refreshment Break/Poster Session – **9:20 am–9:40 am** – Foyer

PANEL SESSION: MATERIAL COMPATIBILITY – **9:40 am–11:40 am**

Lunch on Your Own/Posters – **12:00 pm–1:00 pm**

6E – Electric Vehicles IV
TESTING – **1:00 pm–2:20 pm**

Refreshment Break/Poster Session – **2:20 pm– 3:00 pm** – Foyer

[TESTING CONTINUED] – **3:00 pm– 4:20 pm**

CLOSING REMARKS: 4:20 pm–4:30 pm

3E Salon EFGH

Electric Vehicles I

TOPIC: COMMERCIAL EV

Session Chair: Hyeok Hahn, Chevron, Inc., Richmond, CA

9:20 - 9:40 am
3961325: Hardware and Lubricant Considerations for Commercial Vehicle Electric Drive Fluids (EDFs)
Ian Stewart, Chris Cleveland, Michael Glasgow, Dan Horvath, Tracy McCombs, Stephen Walker, Afton Chemical Corporation, Richmond, VA; Amy Zyski, Darren Ziskovsky, Bill Waltz, Dana Incorporated, Maumee, OH

The global shift from combustion engines to electric vehicles requires ingenuity in driveline hardware. Transmission and axle designs are being wholly reimagined to enable electrification, requiring the introduction of new gear and bearing configurations to accommodate the higher rotational speeds, loads, and stresses associated with electric motors, along with new coating and sealing materials to protect power electrics and other componentry. As eMobility expands beyond passenger vehicles (PV) and other light duty (LD) applications to commercial vehicles (CVs; Class 6-8), drivetrain designs are further increasing the performance and compatibility demands placed upon lubricants used in these applications. Existing electric drive fluids (EDFs) must adapt to meet these needs. Here, hardware design considerations for CV electrification are expounded. The effect of different variables driving the balance between individual lubricant performance requirements for CV battery, eMotor, inverter, and gearbox systems is presented. The relevance, or potential lack thereof, of standard ASTM guidance or contemporary PV/LD EDF criteria, such as durability, oxidation, and materials compatibility, for gauging EDF and CV affinity is discussed. Likewise, conventional driveline fluid formulation styles and componentry need to be reconsidered (i.e. ATF vs MTF vs Axle et.). This presentation will explore those challenges and the merits of parallel hardware and EDF formulation during development.

TOPIC: FLUIDS

Session Chair: Hyeok Hahn, Chevron, Inc., Richmond, CA

9:40 - 10:00 am
3935796: Novel EV Fluid Formulation Developments to Enhance Performance and Meet OEM EV Fluid Requirements
Babak Lotfi, Gordon Lee, ExxonMobil, Annandale, NJ

Early fluid solution approaches for lubricating electric vehicle gearboxes mostly involved utilizing existing, off-the-shelf ATF’s. These fluids were lower in viscosity than their traditional gear oil counterparts, and readily available to manufacturers through existing fluid inventory. As gearbox designs have matured, the first-generation fluid designs are proving to be no longer appropriate, leading to the need for bespoke fluids with targeted performance properties. Over recent years, integrated electric drive units (eDU) where a single fluid is being used to lubricant gears, bearings, clutches and also used for thermal management of e-motor and electronic components has become popular in electric vehicle powertrain designs. These integrated systems provide additional challenges and opportunities driving lower viscosity formulations, and highlighting the need for dielectric properties, thermal management and material compatibility. In this presentation we will review our current work in developing optimized fluids specifically engineered to enhance fluids properties in 3 key areas – Energy efficiency (leading to reduced battery stress and potentially extending driving range), Low Speed Wear (protecting the gearbox), and Aeration (tie back into efficiency, new & aged oil). We will compare the results of different formulations and discuss how we can improve key performance areas using advanced formulations to deliver superior properties and ultimately meet OEMs requirements.

10:00 - 10:20 am
3940690: Latest Developments in Driveline e-Fluid Types for Electric Vehicle (EV) Transmissions and Axles.
Michael Gahagan, The Lubrizol Corporation, Derby, United Kingdom

Entirely new driveline e-fluid classes are being developed as a now integral part of the electric vehicle (EV) powertrain engineering technology revolution. This has been driven by the need for new dedicated fluids to directly cool electrical components whilst fulfilling the requirements of lubricant thermal and fluid electrical insulating properties and corrosion protection under new, severe operating conditions. Notwithstanding the familiar challenges of transmission, gear, and bearing lubrication; recent research and development has led to such a new e-fluid type by optimizing the additive components present in the e-fluid. Additionally, eliminating the need for sulfur-containing additive chemistry (coined "sulfur-free" technology) has seen state-of-the-art fluid technology types just entering the market, which will be described. Fluid electrical properties will be discussed plus results observed from advanced electrical circuit corrosion methods. The fluid's enhanced ability to effectively protect component hardware in a range of fluid viscosity types will also be highlighted.

10:20 - 10:40 am
3975098: The Next Generation Ultra Low Viscosity Electric Drive Fluids (EDFs) Enabled by the Synergy Between the Additive and Base Oil Technologies
Chris Cleveland, Christopher Gowdy, Ian Stewart, Michael Meffert, Afton Chemical Corporation, Richmond, VA; Jason Rosalli, Jason Wells, William Downey, Novvi, Alameda, CA

As the industry continues its transition to electrified vehicles, there is an ever-increasing emphasis on the role of the electric drive fluid (EDF). One specific area of focus in the design and development of the fluid is energy efficiency, which has to do eAxle operation and battery range. In order to achieve these efficiency gains, the implementation of ultra-low viscosities (KV(100C) < 4 cSt) and novel additive and base oil technologies to mitigate churning and frictional losses. Such EDFs are only viable when the additive and finished fluid formulations are robust and balanced to provide the appropriate level of wear, scuffing and pitting protection, oxidation prevention and compatibility with and protection of the key materials components. In this presentation, we will review some recent work in the development of such EDFs.

10:40 - 11:00 am - **POSTER BREAK**

11:00 - 11:20 am
3962846: Improving Heat Transfer Properties of EV Transmission Fluids Using Oil Soluble PAGs
Steffen Glänzer, Clariant, Frankfurt, Germany

Several key parameters, such as anti-wear properties, energy efficiency, electric properties, foam, and material compatibility, must be considered when developing formulations of transmission fluids for electric vehicles. It is especially desirable to maximize the heat transfer properties of these fluids in wet motor applications to improve the efficiency of the electric motor. PAG Group V base fluids are well known in industrial applications, such as industrial gear oil, compressor fluids and hydraulic fluids. However, the immiscibility with hydrocarbons limited their application in automotive oils so far. Here, we will discuss new ultra-low viscosity PAG Group V base oils that demonstrate exceptionally high heat transfer properties, are hydrolytically stable and are compatible with Group I-III mineral oils, Group IV PAO and Group V ester base oils. These mixtures show enhanced properties and can improve vehicle efficiency in wet transmission fluids.

11:20 - 11:40 am
3962676: Effect of Polymers on the Electrical Properties of Lubricants for EVs
Jacob Scherger, Functional Products Inc., Macedonia, OH

One of the key areas specified in the SAE J3200 'Fluid for Automotive Electrified Drivetrains' standard is the electric properties of the fluid. It will become important for formulators to know how different types of additives might affect a fluid's conductivity, dissipation factor, and/or dielectric breakdown voltage. Optimal performance in terms of electrical properties will likely not involve maximizing or minimizing any of these properties, but operating in a moderate range to both prevent static build-up (where sudden releases lead to pitting in bearings, or where fires might occur in extreme cases) and current shorting to unwanted areas or components. In this study, the effect of polymer additives on a lubricant's electrical properties are examined in terms of polymer chemistry, polymer concentration, and base fluid. Polymers have unique physics due to their macromolecular structure, which can affect surface chemistry and mass or charge transport through bulk fluids. The strength of these effects are compared to those of non-polymer additives.

11:40 am - 12:00 pm
3960387: Dedicated E-Fluids for Energy Efficiency
Hitesh Thaker, Changlin Zhao, Infineum USA L.P., Linden, NJ

The automotive industry trends toward improved fuel efficiency and CO_2 emission reduction have resulted in automotive manufacturers incorporating greater levels of electrification, and developing more compact, higher voltage designs. The new generation e-fluids for these applications need to offer reduced energy consumption at lower viscosities while providing necessary hardware protection. Careful optimization of e-fluid parameters like viscometrics and additives is required to achieve high energy efficiency in controlled testing environments and real world conditions.

4E	Salon EFGH

Electric Vehicles II

PANEL SESSION: ESTERS

Session Chair: Neil Canter, Chemical Solutions, Willow Grove, PA

1:15 - 1:30 pm
3957569: Using Synthetic Esters as Performance Components For E-Fluids
Siegfried Lucazeau, NYCO, PARIS Cedex 08, France

It is now generally recognized by the industry that direct cooling in e-mobility applications delivers extended hardware lifetime as well as improved energy efficiency. Synthetic esters, when carefully designed, do possess high performance features for such applications: excellent heat transfer properties, a high level of fire safety, low traction coefficients, and superior resistance to oxidation. It has also been shown such esters did not affect the performance of additive packages on copper protection or mechanical properties. This work has been extended to blends of esters with group III base fluids, considering two different approaches: introduce a hydrocarbon in an ester base fluid, to improve cost-effectiveness and reduce its impact on elastomers- boost the performance of a group III based formulation using esters to reduce traction and improve fire safety. Making blends allows formulators to find ways around some of the drawbacks of both group III and synthetic ester base fluids.

1:30 - 1:45 pm
3959434: Engineering Synthetic Electric Vehicle Lubricants (EVL): New Concepts – Electrical Properties & Thermal Control
Hoon Kim, Zschimmer-Schwarz US, Gordon, GA

EV runs on high voltage electrical power, and battery pack, inverter & electric motor are three essential components of the EV powertrain system. Compact battery packs with high energy density and high-speed electric motor generate excessive heat. Accordingly, proper electrical properties and better thermal control are critical requirements of EV lubricants that are new concepts in lubricant industry. With that, synthetic esters (Gr V) and PAO (Gr IV) are by far the most promising base oil candidates to date to accommodate those key requirements. Especially, the unique polar nature of synthetic esters is more beneficial to accomplish subtle/optimal balance between dielectricity and conductivity under the electromagnetic stress circumstances during the EV operation. In addition, synthetic esters have high thermal conductivity and heat capacity to enhance cooling capacity. Along this line, in this presentation we report our latest investigation on useful structure-property-performance relationships of synthetic esters for EVL application in terms of their various electrical properties including dielectric constant, power factor/loss factor & resistivity/conductivity and thermal properties such as thermal conductivity and specific heat capacity.

1:45 - 2:00 pm
3959714: Sustainability Effects of Esters in Electric Vehicle Lubricants – Efficiency and Biobased Content.
Alexei Kurchan, Gareth Moody, Cargill Inc., Wilmington, DE

The increase in electrification of vehicles can have a dramatic impact on lowering CO_2 emissions. Lubricant can further improve sustainability benefits via improving intrinsic and extrinsic aspects of EV operation and maintenance. The intrinsic benefits are provided by using biobased raw materials. Here, the CO_2 created in production and transportation of lubricants can be partially or entirely offset by carbon sequestration during growing of crops. The second, extrinsic benefits are gained from increased efficiency and extension of vehicle range. This talk will combine both these effects and discuss how the holistic approach to lubricant formulation can have the maximum impact on sustainability.

2:00 - 2:15 pm
3962962: Optimizing EV Fluids by Balancing Performance and Sustainability with Ester Technology
Jared Nelson, Emery Oleochemicals, Cincinnati, OH

Thermal management fluids will be a vital part of the new generation of electric vehicles. While most battery systems currently use indirect cooling systems, it is assumed that in the future either direct or immersion cooling techniques will be implemented. For these high-efficiency systems, a new generation of fluids will need to be developed moving away from traditional water-glycol blends. Esters can play an important role in the formulation and development in of new EV fluids. This Gp V base stock chemistry has shown to have higher breakdown voltages as well as more favorable combinations of low viscosity and high flashpoint. Due to higher costs for more advanced ester technology, blends with petrochemical base stocks can provide a good balance of material sustainability, system sustainability, high performance, and economics. In our latest research, we have evaluated the dielectric and cooling properties of ester blends with petrochemical base stocks.

2:15 - 2:30 pm - **Panel Session Questions**

2:30 - 3:00 pm - **POSTER BREAK**

TOPIC: FOAMING

Session Chair: William B. Anderson, Afton Chemical Corporation, Richmond, VA

3:00 - 3:20 pm
3960517: Low Foaming/Aeration and Low Traction Coefficient Synthetic Lubricant Solutions for High-Speed Electric Drivetrain Fluids
Philip Ma, Donna Mosher, Chad Steele, BASF, Tarrytown, NY

Internal combustion engines (ICE) are being replaced by electric motors as power sources for both passenger cars and heavy-duty trucks. OEMs are using off-the-shelf lubricant fluids, such as industrial gear oils (IGO), automatic transmission fluids (ATF), manual transmission fluids (MTF), dual clutch transmission fluids (DCT), etc. as electric drivetrain fluids (EDF). EDFs are driving toward lower viscosity for better heat transfer capacity and better energy efficiency, and in the meantime satisfying all the other challenging requirements, such as gear/bearing scuffing/wear protection, coating/seal material compatibility, electric properties, etc. In this paper, we will highlight the importance of low foaming and low aeration, low traction coefficient which are critical for the performance of low viscosity EDF during the high rotation-per-minute (rpm) speed applications. EDFs with ultra-low foaming/aeration can potentially reduce electric induced bearing damage (EIBD), bearing creep (BC), thus provide better bearing protection and life, and in the meantime provide better heat transfer capacity. Low traction coefficient fluids will also contribute to better lubricant energy efficiency in comparison to other fluids with the same viscosity.

3:20 - 3:40 pm
3969218: A Study of the Effects of Foam and Antifoam Performance in Electric Vehicle Base Fluids
Safia Peerzada, Münzing North America, LP, Bloomfield, NJ

As electric vehicles (EVs) enter the automotive market, one vital area involves the development of fluids specifically for EVs. Compared to fluids for traditional Internal Combustion Engine (ICE) vehicles, fluids for EVs are required to provide lubrication and cooling under much higher shear conditions and are also required to stabilize the vehicle's electronics and battery's temperature. These different requirements often lead to EV base fluids exhibiting different foaming tendency compared to traditional fluids due to the different fluid chemistry and viscosity. While the fluid is in use, the antifoam functions to minimize foam buildup, which is undesirable for reasons such as reduction of lubrication and poor heat removal. A study of foam tendency in several EV base fluids using new foam test methods to simulate real world application will be reviewed. Furthermore, the performance of various antifoam chemistries will be studied to understand the most optimal antifoam for EV fluids.

3:40 - 4:00 pm
3964246: Electric Vehicle Drive System Specialty Fluids
Anant Kolekar, Valvoline LLC, Lexington, KY

The recent growth in the electric vehicle (EV) market has significantly affected the automotive industry along with the lubricant industry. For the lubricant industry, EV requirements are unique compared to Internal Combustion Engine Vehicles (ICEVs) where electrical, thermal, extreme pressure and foam performances are becoming more critical. The driving range or efficiency and the durability boost are becoming significant goals for EVs that pave the way towards a greener future. In EVs, Gears and bearings rotate at very high speeds (8,000-30,000 RPM) and experience significant fluctuations in power, torque and speed which demand for more precise testing work to improve standard ICEV transmission fluid tests. EV DSFs target vital EV requirements to improve friction reduction, overall efficiency, electrical compatibility and insulation, and electric motor and drive system heat transfer. There is an imperative need to design the best of all worlds EV fluid that maintains excellent mechanical, electrical and tribological properties to give optimal driving range and fuel economy performance. The unique benchtop test is developed to study further on the high-speed foam impact. Different ingredients were compared by designing and developing benchtop tests, transmission rigs and full vehicle tests. There were significant improvements in the overall vehicle efficiency (up to 3%) and reductions in operating temperatures (up to 9 °C).

4:00 - 4:20 pm - **POSTER BREAK**

4:20 - 4:40 pm
3964010: Aeration Characteristics of EV Transmission Fluids: Testing and Comparison Between Specifications
Ricardo Hein, CONEXO, Inc., Acworth, GA

Previous STLE meetings addressed oil aeration as a key stressor for E-fluids operating in EV transmissions. This talk will present the comparative testing results of EV transmission fluids, the apparatus, and the testing method. It includes information on how this efficient and cost-effective tester simulates the complexity of EV transmission operation in order to correlate the aeration characteristics in E-fluids. Under the newly developed testing method, the fluid volumes are reduced, the speed is increased to ultra-high, the air dispersion gear is fully immersed, and the temperatures are raised. We compared several market-available fluids that ranged in quality and specifications. This benchtop aeration tester offers a concrete solution to rethink the fluid design and hardware architecture for low aeration. Manufacturers of EV transmissions, E-fluids, antifoam agents and other additives will benefit from the implementation of this testing method.

TOPIC: GREASE

Session Chair: William B. Anderson, Afton Chemical Corporation, Richmond, VA

4:40 - 5:00 pm
3959450: Greases Based on Perfluoropolyether (PFPE) Oils for E-mobility High Speed Bearing
Greg Poterala, Solvay Specialty Polymers, Commerce Township, MI

The shift towards electric vehicles plays an important role in the transition to a more sustainable mobility. Electrical powertrains are pushed to higher rotational speed in order to efficiently improve the power density. This brings new challenging requirements for the roller bearings, in which advanced EV grease formulations are needed to reduce friction, wear, and NVH on long run while preventing electrical erosion. To address these challenges, we have tested different grease compositions based on PFPE. These fluids are synthetic lubricants largely used for highly demanding applications thanks to their outstanding thermal and oxidative stability, chemical inertness, and hydrolytic stability. In this presentation, we will report the influence of the characteristics of the grease components on the bearing performance at high speed: the viscosity of the PFPE base oil, the type of thickener as well as the additives. We will also discuss the optimization of the electrical properties of the PFPE-based lubricating grease for EV bearing application.

Wednesday, November 15, 2023

5E Salon EFGH

Electric Vehicles III

TOPIC: MODELLING

Session Chair: Babak Lotfi, ExxonMobil Technology & Engineering, Annandale, NJ

8:00 - 8:20 am
3959913: Modelling of the Triboelectric Contact of a Roller Bearing
Stefan Paulus, Simon Graf, Oliver Koch, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

In modern inverter-fed electric drive systems, rotor bearings are loaded by parasitic voltage. When this voltage exceeds the breakdown voltage of the lubricant, it discharges across the lubrication gap. This can lead to damages and premature failure of the used roller bearings. To understand and predict the electrical phenomena inside a rolling contact, roller bearings have to be described as electrical circuit system. In this work, the transfer from the mechanical component roller bearing to an electrical equivalent system is shown. Furthermore, the electrical properties of roller bearings are modeled regarding the capacitive and resistive behaviors of the lubricant and the bearing components. In addition to that, the resistance of occurring discharge channels is taken into consideration. The investigated parameters include the running speed, the ambient lubricant temperature and the mechanical and electrical load. With help of this model, the influence of the operating conditions on the electrical behavior of a roller bearing can be described.

8:20 - 8:40 am
3962867: Simulation of Electrical Properties of Drive Trains Including Bearings and Gears
Hannes Grillenberger, Andreas Meinel, Bernhard Jakob, Martin Correns, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

Electric potentials in generators and electric motors may cause damaging parasitic currents in drive train components like bearings or gears. These currents can lead to subsequent damages like re-melting, re-hardening, grey staining, or aging of the lubricant. An effective and efficient design of the gearbox or motor can only be achieved by simulation that includes mechanical, thermal, and electrical properties for every operating condition. The presentation shows a method to calculate these properties for gears and bearings within a mechanical system. It considers the exact geometry, load distribution, friction, surface roughness, and lubrication conditions. This detailed knowledge enables high quality results, and the system can be optimized for a variety of load cycles. This presentation shows physical background, implementation in a software tool, method workflow and validation. Finally, some corrective measures to avoid parasitic currents will be introduced.

8:40 - 9:00 am
3950663: Modeling Electrical Contact During a Rolling Vibratory Motion Considering Mixed Lubrication
Robert Jackson, Auburn University, Auburn, AL; Santosh Angadi, Gannon University, Erie, PA

In many devices and applications, electrical contacts are exposed to vibrations, sliding, or rolling conditions and are prone to the fretting-based degradation. This could also have applications to electrified rolling element bearings, such as in electric vehicles. Thus, lubricants are often employed in such contacts to reduce wear and fretting corrosion. However, due to the non-conductive behavior of the lubricants with fluorocarbons and hydrocarbons, lubricants lead to a few adverse problems. Also, the fluid dynamics upon excitation, motion causes extended breaks or gaps in between the conducting surfaces. Factors such as surface roughness and fluid viscosity will determine the time taken for the two surfaces of the connectors to separate from a solid conductive contact. In this work, a coupled structural-fluid theoretical model is developed for evaluating such intermittent contact breaks/gaps when two metallic rough surfaces in contact are under vibrations. The model is capable of predicting the increase in the fluid film as well as the contact resistance change with time due to the possible connector vibration.

9:00 - 9:20 am
3962949: Evaluating the Potential Impact of Lubricant Cooling Capability: Applying and Constructing Thermal Models for HEV and EV Drivetrains
Tim Newcomb, The Lubrizol Corporation, Wickliffe, OH

The importance of cooling electric motors is driving the construction of e-lubricants that are optimized for heat transfer. The lubricant properties that influence heat transfer are viscosity, thermal conductivity, specific heat capacity and density. The importance of each depends on the flow regime. There are many electric drive unit configurations and, without design details or access to actual hardware, flow regimes can only be approximated or guessed. The lubricant's heat transfer ability can be assessed using a "figure-of-merit", which incorporates the flow regime impact on the thermal properties. In this presentation we will review the figure-of-merit models as they relate to lubricant thermal properties and compare them to models derived for general e-motor systems where some of the design information is known. We will share our work on the thermal characterization of actual electric drive unit hardware and contrast the thermal models constructed from this work to the prior estimates.

9:20 - 9:40 am - **POSTER BREAK**

PANEL SESSION: MATERIAL COMPATABILITY

Session Chair: Matthias Hof, Emery Oleochemicals GmbH, Duesseldorf, Germany

9:40 - 9:50 am - **Problem Description**

9:50 - 10:05 am
3894802: Conductive Layer Deposits and the Development of Bench Test Technology for Electric Vehicle Drivetrains
Greg Miller, William VanBergen, Savant Inc., Midland, MI; Alexei Kurchan, David Gillespie, Cargill, Newark, NJ; Gunther Mueller, APL, Landau, Germany; Timothy Newcomb, Gregory Hunt, The Lubrizol Corporation, Wickliffe, OH

As the enhancement of EV technology continues, so do the improvements with fluids and additives utilized within them. Varying conditions, depending on the EV system and usage, can cause the formation of conductive deposits and corrosion within drivetrain. Corrosion is a well-known entity and tools to evaluate under these conditions are imperative. However, the formation of conducting layer deposits, a corrosion product, has also been identified as a failure mechanism for current electric motor designs. Different drivetrain base stocks along with additive formulations may have inherently different corrosion rates producing conducting layer deposits in both solution and vapor phases. To help resolve these issues, a group of industry experts involving both OEM's and lubricant experts from across the globe, have developed bench tests to better predict these conductive and corrosion deposits. The apparatus' developed are the conductive deposit test and the wire corrosion test. This paper covers several different aspects of the EV drivetrains and fluids performing in the CDT and WCT that show correlation to field data along with reactions due to the dilution of esters, base stocks and traction reducers.

10:05 - 10:20 am
3939138: Impact of Thermal Transient Effects on the Corrosivity of Lubricants: Part 1 Results of Cyclic Temperature Profiles
Gregory Hunt, Lindsey Choo, Tim Newcomb, The Lubrizol Corporation, Belper, United Kingdom

Lubricant corrosion performance is generally assessed isothermally. The selection of the test temperature has a large influence on the extent of corrosion, typically higher temperatures are more severe. However, vehicles operate over a variety of temperatures, with fluctuations from the nominal temperature being common. There is a question as to whether a short excursion to high temperature would negatively influence the corrosion once the fluid has returned to the nominal condition. This transient temperature relationship with corrosion performance has not previously been investigated. Corrosion is typically assessed using the ASTM D130 copper corrosion strip test which provides a visual rating. However, as the ASTM D130 is a qualitative test, it is not an optimal tool for this type of investigation. A more appropriate method is the Wire Corrosion Test (WCT) because this test follows corrosion processes by monitoring changes in resistance. The WCT therefore is both quantitative and highly sensitive. In this first study, a set of sulfur containing oils was exposed to a cyclic thermal profile, where the temperatures were transitioned between high and low values. The corrosion during the cycling test was found to be more significant than expected. This implies that brief excursions at high temperatures could have greater impact on the corrosion performance over the life of the lubricant than previously expected this is of particular interest in Electric Drive Units (EDUs).

10:20 - 10:35 am
3962166: Effects of Test Conditions on an Oil Emersed Energized Copper Circuit Board
Scott Campbell, Infineum, Linden, NJ

An energized copper corrosion test (ECT) has been developed to study the effects on copper surfaces as may relate to the performance of e-Fluids used in areas such as motor, battery, and electronics. Performance of fluids in these areas is critical to the effective implementation of current and next generation Electric Vehicle drivelines. Energized corrosion testing is still evolving with much variation in competing test designs. This presentation is intended to highlight learnings centered around the variations of certain physical test parameters and their effects on test outcomes.

10:35 - 10:50 am
3964730: Electrification Effects on Oxidation Performance and Corresponding Changes in Dielectric Properties of Drivetrain Lubricants
Joshua Conner, Southwest Research Institute, San Antonio, TX

As electric drive unit design continues to incorporate a common fluid for lubrication of the rotating components and cooling of the electric motor, the electrification of lubricant testing equipment enables test methods that are more representative of electric vehicle applications. This study evaluates: 1) how oxidation affects the dielectric properties (relative permittivity, dissipation factor, electrical conductivity, and dielectric breakdown voltage) of various drivetrain lubricants and 2) how oxidation performance may be impacted by different types of electric and magnetic fields. A common drivetrain lubricant oxidation test was used to study these effects, under both electrified and non-electrified conditions.

10:50 - 11:05 am
3955654: Electric Motor Winding Durability: A simple Ex Situ Test for Determining the Integrity of Insulating Coatings on Conductive Metal Wires
Richard Brenda, Tyler Petek, Lubrizol Ltd., Derby, Derbyshire, United Kingdom

Electric motors in automotive applications have led to new material challenges for the working fluids which enable their operation, including lubricants. One such challenge is the new introduction of polymeric materials used as thin film insulators on copper windings in a motor. Thin motor windings must be electrically insulated from each other to enable high power density motor function. Insulator degradation leading to electrical shorts may result in catastrophic motor failure. Specific application testing is needed to ensure that the insulation properties are not harmed during the motor lifetime. For this purpose, this presentation will discuss a simple test developed to measure the effects of long-term exposure of insulated wires to the lubricating fluid. The test uses industry standard wires with a polyimide type coating and measures their post-exposure insulating properties. The wires undergo accelerated aging in different fluids at high temperature. Once the aging is complete, the wires are installed into the test cell where a conductive fluid fills any void which may have formed in the coating. This creates an ionically conductive path to the wire. A standard potentiostat measures the conductivity through the voids to quantify the coating void fraction. The test can differentiate between fluids that will harm the coating and those that will not whilst also measuring the functionally important properties.

11:05 - 11:20 am
3955641: Investigation of Magnet Wire Compatibility with Electric Transmission Fluids for Enhanced eMotor Performance
Yungwan Kwak, Afton Chemical Corporation, Richmond, VA

The implementation of new global regulations aimed at reducing pollutants, greenhouse emissions, and improving fuel economy has prompted OEMs to accelerate vehicle electrification efforts. In this regard, the electric motor (eMotor) plays a crucial role as one of the key components in the electric drive unit. The eMotor utilizes a significant amount of magnet wire (MW), which is a copper wire coated with a polymeric insulation material that comes into contact with an electric transmission fluid (ETF). Therefore, the compatibility of MW with ETFs emerges as the primary performance requirement, as poor compatibility can result in decreased performance, electrical shorts, or even catastrophic eMotor failure. This talk presents new insights into MW compatibility with various ETFs. Key performance criteria investigated include adhesion, breakdown voltage, and partial discharge behavior of the insulation coating. The study investigates MWs with different shapes (round and rectangular) and various types of coating materials, such as polyester, polyamide, and polyimide. Furthermore, the impact of water concentration in ETF on MW performance during aging is examined. It is demonstrated that the additive package or formulation chemistry of the lubricant plays a pivotal role in generating significant differences in MW performance. The authors elucidate the mechanisms behind MW deterioration and propose strategies for optimizing lubricant formulations to enhance MW compatibility.

11:20 - 11:40 am - Panel Session Questions

6E Salon EFGH

Electric Vehicles IV

TOPIC: TESTING

Session Chair: Leonardo Farfan-Cabrera, Instituto Tecnológico Y De Estudios Superiores De Monterrey, Monterrey, Mexico

1:00 - 1:20 pm
3963994: "E-Mobility an Ever-Changing Landscape for India – Latest Update on Customized Fluids Development"
Sarita Seth, Indian Oil Corporation Ltd., Faridabad, Haryana, India

Out of variety of emerging new transmission designs for electric vehicles, Indian market is dominated by e-axle configuration with single, double or multiple speed gear box for most of the battery powered electric vehicles (BEVs). Wide variety of transmission fluids are being used for lubrication of gears, bearings and other hardware parts. These fluids include, API GL4, GL5, dedicated manual transmission fluids (MTFs), Automatic Transmission Fluid (ATFs) and some dedicated products for specific OEM applications in various viscosity grades. Lab scale evaluation through bench level tests is the key in finding the perfect lubrication strategy to get the best performance from the potential electrified solution as these fluids represent a new challenge for lubrication such as electrical breakdown, heat/thermal management in addition to conventional performance challenges like cooling & anti-wear, bearing protection, NVH and efficiency. Role of base oils and additives in finished lubricants is still to be evaluated in wider perspective. This paper focuses on lab studies of compositions based on varying additive chemistries and base oils in line with SAE J3200 specification meeting the requirements of the various segments of the Indian Market.

1:20 - 1:40 pm
3959446: Application of the Four-Ball EP Test as an FZG (A10/16.6R/90) Scuffing Screening Test with Reference Fluid Assessment
Kerry Cogen, Yanzhao Wang, Infineum USA L.P., Linden, NJ

Scuffing performance is a key metric in assessing electrified vehicle fluid performance. The FZG (A10/16.6R/90) gear scuffing test is typically used, but it is resource intensive. A bench screener test, based on the 4 Ball EP Test (ASTM 2783), has been developed to facilitate prioritizing oils to be run in the more resource-intensive gear test. The screener test also makes it possible to study the formation of tribofilm as a function of load. This systematic approach to analyzing film formation with load offers the opportunity to better understand tribofilm formation and the impact on scuffing performance.

1:40 - 2:00 pm
3964021: Investigation of the Discharge Voltage in EV Motor Bearings
Liang Guo, Henk Mol, Lieuwe de Vries, Thijs Nijdam, SKF Research and Technology Development, Houten, Netherlands

As the automotive industry shifts towards electric vehicles (EV), the issue of electric discharge in motor bearings is increasingly gaining attention due to its potential to cause damage on bearing surfaces and even lead to premature failures. The level of discharge damage is directly influenced by the discharge energy, which, in turn, is dependent on the bearing capacitance and discharge voltages. To gain insights into the discharge voltage within EV motor bearings, electric discharge tests were conducted using in-house developed Tractor equipment, which enables the accurate reproduction of real-world application conditions. The test findings confirm that the discharge voltage follows a probabilistic distribution and is contingent upon the working conditions. The presentation will comprehensively cover essential aspects, including the design of the test rig, the precise acquisition and extraction of the discharge signal, the analysis of damaged surfaces and a comprehensive model explaining the distribution of discharge voltage.

2:00 - 2:20 pm
3953867: Validation of EV Fluids: An In-Depth Exploration of System Efficiency, Durability, and Thermal Performance
Flavio Sarti, TotalEnergies, Solaize, France

The electric vehicle industry has advanced rapidly. As new electric powertrain technologies continue to evolve, new and promising prospects for electric vehicle fluids are emerging. Multi-purpose fluids (lubrication, thermal control, component protection) are starting to be used, which raises the question of how to develop and validate them. The classic approach to transmission fluid development consists of multi-level testing (from contact (tribometers) to components (gears, bearings, pumps, seals) to final application in the vehicle). To enhance this approach, TotalEnergies is incorporating novel in-house tests derived from previous EV fleet campaigns. The use of vehicle data and fluid samples is essential to shorten the testing cycle while maintaining the representativeness of a real road test.

2:20 - 3:00 pm - POSTER BREAK

Session Chair: Carlos Sanchez, Southwest Research Institute, San Antonio, TX

3:00 - 3:20 pm
3952381: E-Fluid Effects Made Visible Through Full-Scale EDU Testing
Suzanne Patterson, Auke Faber, David Whitticar, The Lubrizol Corporation, Wickliffe, OH

The global transition to electrified powertrains necessitates new lubricants which provide e-device durability, minimize power loss, and participate in thermal management. The correlation of mechanical efficiency in traditional gear boxes to fluid viscosity, traction, and friction has been extensively studied, and we are now studying those correlations to power loss in e-axles, with and without embedded motors. We are also studying the relationship between thermal management of an e-device and a fluid’s viscosity, heat capacity, and thermal conductivity. For full scale electric drive unit testing, Lubrizol has upgraded our three-motor transmission test stands with the addition of a 400 kW battery simulator and can precisely control embedded electric machines with a pair of universal inverters. This upgrade allows testing of myriad lubricants in almost any e-device, generating fundamental knowledge for how to formulate the highest performing e-fluids.

3:20 - 3:40 pm
3962033: Development of High-Speed/High-lLad Three-Roller Type Pitting Wear Tester for Tribo-Elements Sliding Parts of Electric Vehicle
Takuto Kunii, Vishal Khosla, Jun Xiao, Michael Vinogradov, Rtec-Instruments, Chiba, Kashiwa, Japan; Shinya Sasaki, Tokyo University of Science, Tokyo, Japan

The E-Axle as a transmission/motor system in electric vehicles is becoming an alternative to traditional engines. In the development of the E-axle, increasing the rotation speed of the motor and improving the efficiency of the transmission are urgent issues in order to make the system more compact. The high-speed rotation of the transmission and the resulting low viscosity of the lubricating oil affect the poor lubrication of the gear and bearing surfaces and the increase of pitting wear. Pitching wear causes transmission vibration and noise and reduces powertrain efficiency and life. In this research, we have developed a three-roller pitting wear tester that enables higher speed (>4.0m/s) and higher load (>2000N) testing. Using this device, we investigated the effect of the slip ratio on the occurrence and progression of micro-pitting on the rolling friction surface of gear steel using an acoustic emission method.

3:40 - 4:00 pm
3923522: The Investigation of Lubricant Viscosity on Fatigue Wear of Gear/Bearing Steel under Rolling Contact Conditions
Ryotaro Ohashi, Graduate School of Tokyo University of Science, Katsushika-ku, Tokyo, Japan; Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Katsushika-ku, Tokyo, Japan

In recent times, the popularity of electric vehicles (EVs) has grown significantly, necessitating the enhancement of fatigue wear resistance in reducers due to the higher rotational speeds of motors. Lubricant viscosity has been found to affect gear failures like pitting, but the mechanism is not fully understood. In this study, in addition to the rolling-sliding condition, we used a pure rolling condition. Ball-on-disc traction tests with different viscosity poly-alpha-olefin (PAO) were conducted, and the damaged area on the discs was evaluated using a laser microscope and MATLAB. Results showed that increasing lubricant viscosity increased the damaged area on the discs. Higher viscosity in a base oil like PAO increases the pressure-viscosity coefficient, leading to higher contact pressure. This yielded a correlation between the pitting and viscosities of PAO. To optimize the fatigue wear resistance of EV reducers, it is necessary to design lubricant from the fundamental perspective of its viscosity.

4:00 - 4:20 pm
3962105: Effect of Phosphorus and Sulfur Based Additives on Wear and Micro-Pitting Under Rolling and Sliding Conditions.
Yunah Jeung, Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Katsushika-ku, Tokyo, Japan; Ryotaro Ohashi, Kenya Nakayama, Graduate School of Tokyo University of Science, Katsushika-ku, Tokyo, Japan

As the E-axle is being made smaller, the speed of motor rotation is increasing, and low-viscosity transmission lubricating oil is required in order to reduce stirring resistance and improve cooling performance. As a result, the gears and bearings of transmissions are forced to move under poor lubrication conditions, so lubricating oils are required to have further improved wear resistance. Phosphorus- and sulfur-based additives are commonly used to improve wear resistance, but their anti-wear mechanisms are not well understood. As a result of an investigation using a mini-traction machine (MTM), it was confirmed that the S-type additive exhibited a greater anti-wear effect than the P-type additive. The anti-wear and anti-pitting fatigue mechanisms were discussed based on the surface analysis results of the tribo-reaction films on sliding surfaces derived from P-based and S-based additives.

4:20 - 4:30 pm - **Closing Remarks,** Peter Lee, Southwest Research Institute, San Antonio, TX

EVP

EV Posters

3975429: Toward a Single Fluid: Balancing Lubrication and Thermal Management Through $Ti_3C_2T_z$ MXene Nanoparticles
Hong Liang, Texas A&M University, College Station, TX

Mexene particles, $Ti_3C_2T_z$ nanosheets exhibit high thermal conductivity, electrical conductivity, and mechanical strength, making them promising candidates as lubricant additives to design an single fluid for electric vehicles. Using a single fluid in vehicles for balanced lubrication and thermal management can improve fuel economy, reduce emissions, and improve performance. These fluids can be used as transmission, differential, and power steering fluids where lubrication and thermal management are essential factors to avoid the wear of vehicle component. In this research, we evaluate the performance of $Ti_3C_2T_z$ as an additive to enhance the heat transfer, rheological properties, and tribological performance of silicone and polyalphaolefin (PAO) base oils. Experimental results showed that adding $Ti_3C_2T_z$ improved thermal conductivity by 16 % and 23 % in silicone and PAO oils, respectively. The rheological data revealed that adding $Ti_3C_2T_z$ nanosheets reduced the viscosity by 12.3 % (at 0.09 wt%)

and 18.1 % (0.04 wt%) in silicone and PAO oil, respectively. The addition of $Ti_3C_2T_z$ reduced the friction by 23 % (0.09 wt%) and 65 % (0.04 wt%) in silicone and PAO oils, respectively. The improved properties and reduced fluidic drag in viscosity and friction can offer the utilization of $Ti_3C_2T_z$ MXene-based fluid in EVs applications which will help to achieve improved fuel economy by meeting the stringent requirements of EV compared to ICE vehicles.

3965022: Effect of a Bio-Derived Lubricant on the Tribological Properties of Electrified Contacts
Leonardo Farfan-Cabrera, Carlos Rubio-Hernández, Tecnologico de Monterrey, Monterrey, Nuevo Leon, Mexico; Ali Erdemir, Texas A&M University, College Station, TX; Peter Lee, Southwest Research Institute, San Antonio, TX

Interest in highly functional EV Lubricants has increased tremendously. They need to fulfill a wide range of functionality including excellent electrical, thermal, tribological and chemical properties, material compatibility and eco-friendliness. Considering state-of-the-art progress being made in bio-based lubricants, novel fluid formulations using these oils as additives in mineral or synthetic-base oils hold great promise in meeting the multifunctional requirements of EV drivetrains. This work presents the results of a systematic study involving the use of Jatropha crude oil as an additive in a group II Mineral oil on dielectric strength and tribological properties in a four-ball tester instrumented with DC power.

3964760: eTribology – Electrified Mini Traction Machine Test Results
Peter Lee, Carlos Sanchez, Andrew Velasquez, Michael Moneer, Southwest Research Institute, San Antonio, TX

SwRI in partnership with PCS Instruments have electrified a Mini Traction Machine to allow AC and DC voltage with various currents, voltages, and frequencies to be applied across the ball and the disk test specimens. Different behaviors have been observed with the presence of AC and DC voltage versus the non-electrified tests. Traction coefficient across the Stribeck curve increases, as does wear volume and the wear type changes. Lubricants used were an Ultra-Low Viscosity and Dexron VI automatic transmission oil, and an automatic gear oil. Tests were performed at different temperatures and electrified conditions. These results will be presented and discussed.

3964759: eRheology – Test Methods and Analysis of E Lubricants
Carlos Sanchez, Peter Lee, Southwest Research Institute, San Antonio, TX

Lubricants in electric vehicles tend to behave differently in the presence of an electric field. There are many rheological test methods used for engine and drivetrain applications that are relevant to EV systems. Rheology can be used to evaluate lubricants for visco-elastic behavior, churning losses, and viscosity, to name a few. Several lubricant properties were investigated using different rheological test systems while subjected to an electric field. This work will discuss current test methods used for evaluating driveline fluids and greases, and new methodologies being developed to meet the demands of electrification.

3964146: Fluid Durability Study in Electrified Drivetrains
Cole Frazier, Southwest Research Institute, San Antonio, TX

Three complementary programs have been undertaken to determine the real-world conditions that stress a fluid in an electric or hybrid-electric vehicle (EV/HEV) drive unit and determine what a “failed” fluid looks like at the end of its life. By utilizing in-vehicle testing on chassis dynamometers, road conditions have been closely replicated to simulate the stressors that a fluid undergoes during its life cycle. This report provides an update on testing results for the Toyota RAV4 Prime Hybrid and Hyundai Ioniq5 which were disassembled, documented, extensively instrumented, tested for efficiency and range, and set on a 100,000-mile fluid durability test cycle. Incidental findings, used fluid analysis and operational data will be presented from each vehicle.

3963911: Effect of a Protic iInic Liquid on Friction and Wear Performance of an-Ultra-Low Viscosity Synthetic Oil under Electrified Sliding Conditions
Seungjoo Lee, Ali Erdemir, Texas A&M University, College Station, TX; Leonardo Farfan-Cabrera, Tecnologico de Monterrey, Monterrey, Nuevo Leon, Mexico; Patricia Iglesias, Rochester Institute of Technology, Rochester, NY

Market penetration of electric vehicles (EVs) has been growing rapidly in recent years to meet the future transportation needs of world community. As opposed to the tribological issues in traditional internal combustion vehicles, not much is known about the tribological issues in EVs especially under electrified contact conditions. In this study, we used a pin-on-disk machine under ASTM G99 conditions to explore the friction and wear behavior of an ultra-low viscosity oil (PAO 2) under electrified sliding conditions with and without the use of a protic ionic liquid. Combining excellent thermal stability with high electrical conductivity, the protic ionic liquid had a significant positive effect on the friction and wear behavior on steel test pairs. Post-test structural and surface analytical studies revealed the formation of very different kinds of tribofilms when electrified and the ionic liquid was used. Specifically, tribofilms contained higher levels of carbon nanostructures under electrification and in the presence of ionic liquid which together resulted in superior wear performance.