Early Career and Student Research Posters

Early Career research posters

3893542: Effect of Rail Steel Microstructure to the Deformation Layer at the Rail/Wheel Interface

Yue Yang, Roger Lewis, James Ayabina, Kazim Yildirimli, The University of Sheffield, Sheffield, United Kingdom; Gerald Trummer, Klaus Six, Virtual Vehicle Research GmbH, Graz, Austria

In order to improve modelling of wheel and rail materials a better understanding of wear and rolling contact fatigue mechanisms is required. These are both initiated in the deformed layers that are created at the contact surfaces of wheels and rails where the microstructures are heavily affected by the loading cycles applied by the passage of wheels along the rail. The microstructures were compared along with hardness and strain values. A high-pressure torsion (HPT) technique has been developed to create this deformed layer under controlled conditions in the laboratory. In this work tests were carried under different conditions of twist on the HPT machine and the created deformed layers compared to deformed layers in full-scale wheel rail tests and data from the literature taken from rail extracted from the field. The deformed layer so it is critical that the properties reflect those of actual wheel or rail accurately.

3801745: Abrasive Wear – Analysis in the Set Shaft/Bearing of the Mining Industry

Zirlene Santos, Victor Do Carmo, Federal University Ouro Preto, Ouro Preto, Minas Gerais, Brazil

The research has a goal analysis of how abrasive wear causes failure in the set shaft/bearing of the idlers of load in the industry mining-metallurgical. The methodology has been qualitative using experimental and descriptive research. Also, used experimental research. In this sense, two load idlers were compared, the first with the problem by the locking of the inner ball bearing and the second one not yet hit by the jamming. These cuts were done in the casing to perform the failure analysis and determine what causes of fail of the set shaft/bearing. The results of the research demonstrate that the polyethylene retainer and rubber seal of Idlers were worn out for cause ore. For this reason, was allow input ore in the set shaft/bearing. The shaft/bearing also was worn out for causing the lubricate was be contaminated. The polyethylene retainer and rubber seal don't have resistance effective for abrasive wear caused for ore. It needs to change these component's material.

3908214: Eco-Friendly and Antiwear Ionic Liquids Additives in Marine Turbomachinery Lubricants

Wenbo Wang, Tom Geeza, Huimin Luo, Louise Stevenson, Teresa Mathews, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Tidal energy, capable of generating clean and sustainable electricity through turbomachinery, is a promising source of the renewable energy portfolio. The conventional lubricants used in marine turbomachinery are toxic and exhibit low biodegradability, potentially resulting in a serious threat to marine ecosystems in the case of a leak or spill. Therefore, it is crucial to develop an environmentally acceptable lubricants (EALs) with high performance in wear protection. Recently, eco-friendly, high-lubricity ionic liquids (ILs) have been successfully invented at Oak Ridge National Laboratory and being further developed for tidal turbine gearbox lubrication. Compared with the commercial baselines, the 'not toxic' and 'readily biodegradable' IL-additized lubricants performed more effectively in mitigating the friction, rolling contact fatigue and wear loss. The wear modes and ILs' surface protection mechanisms were discussed with the assistance of surface and tribofilm characterization.

3892602: The Sound of Tribology – Music and Sound from the Monitoring of Tribological Components

David Brady, University of Leeds, Leeds, West Yorkshire, United Kingdom; Rob Dwyer-Joyce, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Presenting the results of research in tribology creatively can inspire peopele and make the subject more engaging and accessible. Music has the power to sooth, excite, and inspire. It is one of the basic forms of human sensory engagement. What better way to present the results of tribological experiments than in the form of music. I have used in situ audio recordings and sensor data from both hip replacement simulators and ultrasonic monitoring of piston rings and ball bearings to form an innovative and creative expression of the sounds associated with the research. Measured signals from real tribological experiments have been collected, converted into an audible frequency range and manipulated and effected to create music. The intention is to create audibly pleasant and stimulating sounds. This outreach project shows the data recorded in these research areas in a creative context, giving a different perspective with the intent to inspire and provoke new interest in the tribology field.

3831414: Molecular Dynamics Investigation of the Nanoscopic Friction on Monolayer MoS_2 in the Presence of Water

Igor Stankovic, Miljan Daši , Institute of Physics Belgrade, Zemun, Belgrade, Serbia

In the current work, molecular dynamics (MD) simulations are employed to study the nanoscopic friction on monolayer MoS_2 in the presence of water. The simulation setup mimics atomic force microscope (AFM) experiments by using an amorphous probe made of SiO_2, a monolayer MoS_2 plate, and water molecules in between to simulate conditions due to air humidity. Two systems are compared, with a probe fully immersed in water and surrounded by water, and a water capillary around the probe. In the latter case, the stick-slip friction behavior is pronounced and increases with the normal load. This study demonstrates that water content in the nanoscopic tribosystem of the MoS_2 surface-SiO_2 probe significantly impacts the probe's lateral and longitudinal movements, and therefore, its stick-slip behavior.

3805447: Research on the Deviation of the Temperature Field of the Brake Disc Between the Experimental Test and the Simulation Calculation

Junying Yang, Fei Gao, Dalian Jiaotong University, Dalian, China

Based on the TM-I reduced scale railway vehicle braking test bench, under the conditions of the initial speed of 80, 120, 160, 200 km/h and pressure of 0.5, 0.7, and 0.9MPa, the corresponding temperature field of the brake disc is obtained by using the methods of braking test and simulation calculation, respectively. The results show that the peak temperature and average temperature of the disc obtained by the test are higher than the values calculated by the simulation. The reason for this deviation is that local contact results in a concentration of heat that increases the temperature above the calculated value. The instantaneous peak temperature of the experimental test can reflect the random change characteristics of the actual contact surface. For the simulation calculation, ideal uniform contact conditions are assumed, and the instantaneous peak temperature obtained by the calculation can avoid the influence of the fluctuation factor of the contact surface.

3802614: Influence of Black Oxide Coating on Micropitting and ZDDP Tribofilm Formation

Mao Ueda, Shell Lubricants Japan K.K., Kanagawa, Japan; Hugh Spikes, Amir Kadiric, Imperial College London, London, United Kingdom

Application of black oxide (BO) coating to steel rubbing surfaces has been suggested as a potential approach to alleviate micropitting. This article confirms that BO coatings can prevent micropitting and identifies the predominant mechanism by which this occurs. Micropitting tests were carried out using zinc dialkyldithiophosphate (ZDDP) solutions in a ball-on-disc tribometer. Micropitting was preferentially generated on the smooth balls and this was completely prevented by applying a BO coating to the rougher discs, regardless of whether the balls were coated or not. In contrast, when the rough discs were not BO-coated, micropitting was consistently generated on both BO-coated and uncoated balls. BO coating has about one-quarter the hardness of the steel used and was found to be very rapidly removed from the surface asperity peaks at the onset of rubbing, despite the presence of ZDDP.

Student posters

3929505: Understanding the Friction and Wear Mechanisms of Additively Manufactured Nanocrystalline Al-Mg Components Deposited Using High-Pressure Cold Spray Technique

Amanendra Kushwaha, Manoranjan Misra, Pradeep Menezes, University of Nevada Reno, Reno, NV

In the present work, cryomilling process followed by cold spray deposition was used to manufacture nanocrystalline (NC) Mg-doped Al parts. X-ray diffraction was used to determine the changes in crystallite size and hardness was measured using a Vickers microhardness tester. A pin-on-flat tribometer setup was used to carry out friction and wear tests. The transfer layer was studied using a scanning electron microscope (SEM). The XRD analysis showed that the crystallite size decreased with an increase in the cryomilling time. The Vickers hardness tests showed an increase in hardness with a decrease in the crystallite size. The results also showed that the coefficient of friction and the wear rate decreased with the increase in hardness. In comparison to pure Al, the Mg-doped Al material displayed superior tribological and mechanical properties. The underlying mechanisms for the reduction in crystallite size and its effect on hardness, friction, and wear performance will be discussed.

3919408: Spectroscopic Evaluation of the Surface Chemical Processes Occurring in MoS_2 upon Aging

Nicolas Molina Vergara, Robert Chrostowski, University of Texas at Austin, Austin, TX; John Curry, Michael Dugger, Sandia National Laboratories, Albuquerque, NM; Tomas Babuska, Sandia National Labs, Albuquerque, NM; Filippo Mangolini, The University of Texas at Austin, Austin, TX

Molybdenum disulfide (MoS2) has been used as solid lubricant in aerospace applications because of its low friction response in inert environments. However, exposure to atmospheric conditions and periods of inactivity can cause MoS_2 to "age" into a high friction state. This poses a significant challenge in the reliable use of MoS_2. Despite the volume of the published literature, our understanding of the surface phenomena taking place during aging of MoS_2 is still elusive. Here, we performed XPS and ToF-SIMS analyses to identify the surface chemical changes occurring in MoS_2 upon aging in variable environments.

This work was funded by the Laboratory Directed Research and Development program at Sandia National Lab., a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the US DOE's National Nuclear Security Administration under contract DE-NA0003525.

3908363: Evaluation of Contact Stiffness at the Rough Interface of a Hard-Coated Aluminum with Different Thicknesses

Md Habibur Rahman, University of Illinois Urbana-Champaign, Urbana, IL

Engineering surfaces are rough at the microscale level and consist of multiple asperities. Most of the work done so far on the contact mechanics of a rough surface is mainly focused on the elastic regime. This study discusses the interfacial contact stiffness and contact load distribution in a rough aluminum surface, without and with a hard coating, consisting of many homogenous asperities considering the plasticity. The average asperity radius is varied to observe the behavior of the contact stiffness with increasing normal stress. The contact load-interference relation is investigated for elastic, elastic-plastic, and fully plastic regimes. A mean contact pressure in terms of interference is found to measure the hardness of the material with changing coating thickness. This work can be used to study the plastic deformation in a material, theoretically, at the microscale level, and design an optimum coating thickness to prevent premature yielding in the substrate material.

3905275: Graphene as a Conductivity Modifier in ZDDP Tribofilms for Use in 3D Tribo-Nanoprinting

Simon Duston, Krzysztof Kubiak, Ardian Morina, University of Leeds, Leeds, United Kingdom; Yuechang Wang, Harbin Institute of Technology, Shenzen, China; Rachel Oliver, University of Cambridge, Cambridge, United Kingdom

3D Tribo-Nanoprinting [1,2] uses AFM to additively manufacture 3D structures on the nanoscale using tribofilm formation. For this to be used as a viable manufacturing technique, the tribofilms must exhibit functional properties, such as conductivity. In this work ZDDP tribofilms have been generated, on a tribometer, using a method that allows for graphene nanoplatelets to be dispersed within the volume of the formed films. These films were generated to contain a range of concentrations of graphene and had thicknesses of approximately 150 nm. Conductive and Lateral Force AFM were used to measure the effect of the graphene on the conductivity and friction properties of the tribofilms. It was found that the otherwise electrically insulating ZDDP tribofilms were able to sustain currents through their thicknesses.

Applications for this novel method of additive manufacturing range from biosensors and electronics, to surface patterning and data storage.

Early Career and Student Posters

3908311: Exploring the Dust Tolerance Capability of Al-6061 alloy Fabricated via Directed Energy Deposition Process

Pial Das, Nicholas Dyrstad-Cincotta, Emil Umerov, Sougata Roy, University of North Dakota, Grand Forks, ND; Matthew Mazurkivich, Sara Rengifo, William Scott, NASA, Huntsville, AL

Erosion by high-speed abrasive particles is a major form of material degradation in numerous systems including spacecraft, especially during a landing on an extraterrestrial body. For those spacecraft's part manufacturing material, directed energy deposited (DED) produced Al-6061 has several advantages over traditionally made alloy, i.e., microstructural uniformity, superior mechanical properties, and enhanced wear performance. On the other hand, reinforcement like hBN/TiC gives even higher strength, wear resistance, and density to the Al matrix over conventional Al6061 alloy. While the strength of the material has been finely studied, the erosion performance of those materials has not been extensively explored. In our recent work, we studied the erosion performance of DED produced specimen, simulating the partially lunar environment, searching for optimum reinforcement percentage against lunar dust simulant particle (Lunar Mare Simulant) under varied temperatures (25C~125C) levels.

3907092: Dry Sliding Wear of Metal-oxide Filled PTFE Composites

Jackson Swets, Joseph Berbach, Harman Khare, Gonzaga University, Spokane, WA

The addition of nanoscale alpha-alumina to polytetrafluoroethylene (PTFE) reduces wear of PTFE by nearly four orders of magnitude under dry sliding on steel. Ultra-low wear of alumina-PTFE composites is enabled by growth of robust tribofilms on both the composite pin and steel surface. Tribofilms are developed in part through friction and shear stress as a result of sliding with the availability of ambient humidity. PTFE composites reinforced with certain other metal oxide nanoparticles result in wear rates comparable to alumina, while others result in significantly higher wear for reasons that remain unclear. Brass counter-surfaces are similarly known to result in higher wear, irrespective of filler choice, including alumina. In the current work, morphological and chemical analyses of worn interfaces are used to determine factors – particularly related to chemical interactions in the interphase region and on the counterface that help promote low wear of metal-oxide PTFE composites.

3907889: Effect of W and Mo Alloying Elements on Additively Manufactured Co-Cr Alloy for Prosthodontic Applications

Sudip Saha, Uday Venkat Kiran Kommineni, Xin Zhang, Xiaodong Hou, Sougata Roy, University of North Dakota, Grand Forks, ND; Manikanta Grandhi, Zhichao Liu, West Virginia University, Morgantown, WV

This study examines the impact of W and Mo on the tribological, and corrosion behavior of Co-Cr alloy produced by Directed Energy Deposition. Primary materials study includes powder morphology, alloy microstructure, microhardness analysis and preparation of artificial saliva. Tribological tests were conducted in dry and lubricated conditions using alumina balls as counterpart and both alloys displayed a combination of adhesive and abrasive wear as primary wear mode. CoCrW alloy exhibited increased friction and wear volume with lower hardness compared to CoCrMo. Oxidation behavior and saliva-induced tribo-film formation were analyzed for both alloys. In lubricated tests brittle behavior of alumina balls were observed, while material transfer from flat to ball was captured during dry contact conditions. Corrosion behavior of the alloys was assessed with open circuit potential and potentiodynamic polarization tests.

3907366: Unleashing the Potential of MXene/MoS_2 Nanocomposites for Superlubricity on Rough Steel Surfaces

Ali Zayaan Macknojia, Aditya Ayyagiri, Diana Berman, University of North Texas, Denton, TX

This study presents the demonstration of the macroscale superlubricity state achieved by spray-coating solution-processed multilayer Ti3C2Tx-MoS_2 blends onto rough 52100-grade steel surfaces. The blends exhibited exceptional tribological performance that has not been reported previously for individual pristine materials, MoS_2 and Ti3C2Tx, under high pressure and sliding speed conditions. The study investigated the processing, structure, and property correlation to gain a deeper understanding of the underlying phenomena. Raman spectroscopy, scanning electron microscopy, and transmission electron microscopy results revealed the formation of an in-situ robust tribolayer responsible for the outstanding performance observed at high contact pressures and sliding speeds. This study has broad implications for the development of solid lubricants that can operate under extreme conditions, likely inspiring further research and development in this field.

3908362: Determining the Elastic Modulus and Permeability of High Molecular Weight Poly(Vinyl Alcohol) (PVA) Hydrogels

Nabila Ali, University of Illinois at Urbana-Champaign, Urbana, IL

Hydrogels are semi-solid materials with three-dimensional network structures that can hold a large quantity of water. Physically crosslinked poly(vinyl alcohol) (PVA) hydrogels prepared with repeated freeze-thawing technique have been investigated widely due to their tunable properties and easy synthesis process. While increasing crosslinks improve the overall mechanical properties, the interrelationship between the elastic modulus and permeability with changing composition is still not fully understood. In this poster we have studied the elastic modulus and permeability of high molecular weight PVA hydrogels with compositions ranging from 4 wt.% to 11 wt.%. We have observed that with increasing concentration of PVA, their elastic modulus increases but the permeability decreases. Since these properties affect contact pressure and lubrication, this study can be useful for sliding applications and also for designing biomedical devices in future.

3908360: Development and Performance Evaluation of Novel Surface Polishing Technique for Additively Manufactured Components

Uday Venkat Kiran Kommineni, Sougata Roy, University of North Dakota, Grand Forks, ND; Brady Kimbrel, Marshall Space Flight Center, NASA, Huntsville, AL

A novel and sustainable Dry Electro-MechanoChemical (DEMC) surface finishing technique was devised, which uses dry electrolyte media to improve the surface quality of additively manufactured nitrogen strengthened austenitic stainless steel. Austenitic stainless-steel samples were fabricated using a laser powder direct energy deposition system, following optimization of process parameters. The effect of DEMC electrolyte composition on material removal rate, surface morphology, and surface roughness was studied. Amplitude (Ra, Rrms, skewness, and kurtosis), spatial, and hybrid surface roughness parameters were investigated using white light interferometry technique. The enhancement in surface roughness after polishing validates the capability of DEMC to improve the surface finish of additive-manufactured parts. This research also highlights challenges with DEMC polishing of DED components such as surface pitting and need for precise parameter control to avoid microstructure changes.

3908272: Utilizing the Surface Roughness Parameters of Rods and Friction in Hydraulic Rod Seals to Study Stick Slip

Sean Kwasny, Fluid Power Institute, Milwaukee School of Engineering, Milwaukee, WI

Stick-slip friction in hydraulic actuators can negatively impact machine controllability and operator safety. It is affected by seal type, fluid properties, and the surface roughness characteristics of the rod. While previous studies have investigated the effect of oil composition and seal type, the impact of rod topology has received less attention. This study examines the effect of sliding speeds, pressure, viscosity, and surface roughness characteristics on the reciprocating seal friction. The experimental investigation was conducted using a servo-controlled electric linear hydraulic actuator. The presence of stick-slip was confirmed through fast Fourier transform analysis of force vibrations. Differences in stick-slip behavior were observed for these parameters which were then used to developed model to study stick-slip friction. The study provides a basis for reducing or eliminating stick-slip vibration, thereby improving the control and safety of hydraulic machinery.

3908320: Investigating the Influence of Novel Chemical Modification Process on Enhancing the Tribological Behavior of High Oleic Soybean Oil

Piash Bhowmik, Clement Tang, Sougata Roy, University of North Dakota, Grand Forks, ND; Brajendra Sharma, Majher Sarker, USDA/ARS/NEA/ERRC, Wyndmoor, PA

Soybean oil is currently being studied as lubricating oil in various industries due to its renewability and biodegradability. In this research, High oleic soybean oil's (HOSO) tribological performance was enhanced through a novel chemical modification process that converted unsaturated fatty acids to saturated ones. Gas chromatography-mass spectrometry and nuclear magnetic resonance spectrometry were used to characterize soybean oils. The physicochemical properties of HOSO, chemically modified HOSO, and high oleic sunflower oil were measured. The tribological behavior of the oils was investigated using a ball-on-flat type reciprocating tribometer at room temperature and 100°C. The select chemical modification process increased wear resistance by 17% at room temperature and 8% at 100°C operating temperature. Major differences in wear mechanisms were further analyzed using white light interferometry, scanning electron microscopy, and energy-dispersive X-ray spectroscopy techniques.

3908309: Effects of $Ti_3C_2T_z$ MXene Nanoparticle on Fluidic Properties & Tribological Performance

Kailash Arole, Micah Green, Hong Liang, Texas A&M University, College Station, TX

In this work, 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) 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_2Tz nanosheets reduced the viscosity by 52.3% and 24.3% in silicone and PAO oil, respectively. This non-Einstein viscosity reduction can be attributed to the disruption of hydrophobic interactions of base oil molecules due to the addition of hydrophilic $Ti_3C_2T_z$ nano-sheets, which could disrupt local bonding networks of base oil. The addition of $Ti_3C_2T_z$ reduced the friction by 23% and 65 % in silicone and PAO oils, respectively. The improved properties and reduced fluidic drag in viscosity and friction lead to potential applications in (electrical) vehicles that will be helpful in attaining improved fuel economy.

3908248: Depth-dependent Adhesion of Gradient-stiff Hydrogel, Measured Using AFM Nano-indentation

Md Mahmudul Hasan, Alison Dunn, University of Illinois at Urbana-Champaign, Urbana, IL

Gradient-stiffness, common entity in biological livings, and hydrogels, plays a pivotal role in their physiological and tribological performance. Earlier, we reported that gradient-stiff surface, where stiffness gradually increases into depth, controls the overall contact mechanics. The varying polymer chain density in such surface changes their adhesive interaction, which needs a methodical investigation. Here, we investigated the evolving adhesion into the depth of polyacrylamide hydrogel, molding against different materials, using AFM. Results showed that mold material can tune gradient layer properties on identically-composed hydrogels, i.e., glass-molded hydrogel has thinner gradient layer,~ 150nm, compared to that of Polyoxymethylene-molded hydrogel,~ 450nm. The adhesion at shallow depth was significantly higher with having different probe-sample separation mechanism compared to deep depth. These results allow clear understanding of depth-dependent adhesion in a gradient-stiff surface.

Early Career and Student Posters

3908150: Hydrogel Permeability as a Function of Elastic Modulus for Improving Mechanical and Surface Properties

Nusrat Chowdhury, University of Illinois at Urbana-Champaign, Urbana, IL

Hydrogels are composite materials with high content of water of 90-95% that provides tremendously low friction to the surface. Even though these gels hold high water content, their mechanical strength and structural properties make them feasible for biomedical applications. In our current effort, we have tested 7-11% pAAm hydrogel for their permeability values through a permeability tester and the elastic modulus with micro-indentation. The permeability values for these compositions range from 2 ×10-16 - 2×10-17 m2 and the modulus ranges from 20-80 kPa. The elastic modulus follows an increasing trend with a decrease in the permeability of the hydrogel. As there is an inverse relationship between the modulus of elasticity and permeability, we can have a quantitative idea of permeability value from the modulus of the hydrogels. The higher the strength of the material, the harder it will be to squeeze out fluid from the gels because of the denser polymer content and mesh size.

3907912: Evaluating the Effect of Erucic Acid Content on Tribological Performance and Thermal Oxidation Behavior of Plant-Based Lubricants

Rawan Al Sulaimi, Diana Berman, University of North Texas, Denton, TX

This study compared six plant-based lubricants (Jojoba, Castor, Canola, Rapeseed, Pennycress, and Lesquerella) with PAO4 oil to evaluate their potential as environmentally friendly alternatives to synthetic oils. The results showed that high erucic acid content oils exhibited better lubrication properties and oxidation resistance under high temperature and shear regimes. To further investigate this, the effect of erucic acid on tribological behavior and thermal oxidation was studied by comparing oils with similar structures but different erucic acid contents. The study found that higher erucic acid oils reduced friction and wear on steel surfaces under loads up to 20N and temperatures up to 200C. The study proposes a new approach to enhance the performance of biolubricants by manipulating their molecular structure.

3907519: Tribological Study of a Protic Ionic Liquid as an Additive in Base Oils Under Electrified Conditions

Seungjoo Lee, Ali Erdemir, Pushkar Deshpande, Texas A&M University, College Station, TX; Leonardo Farfan-Cabrera, Tecnologico de Monterrey, Monterrey, Mexico; Patricia Iglesias, Rochester Institute of Technology, Rochester, NY

E-mobility is considered imperative for a sustainable transportation for future. However, not much is known about the adverse effects associated with undesirable passing of electrical current within the moving parts of electric vehicle (EV) drivetrains. Ionic Liquids (ILs) are well-known for their unique physical and chemical properties which might make them potential candidates for use in EV lubricants. Here, we present tribological studies of various base oils (including PAOs and Mineral base oils as well as a lubricant derived from plastic wastes) with and without a protic IL additive under electrified conditions. Results of extensive tribological tests confirmed the existence of unique tribochemistry greatly impacting friction and wear. Base on the results of tribological and analytical studies, we propose a phenomenological model that explains the underlying mechanism for the generation of a highly protective tribofilm under some of the electrified test conditions.

3907498: Mitigating Wear in Knife Mill for Biomass Preprocessing by Applying Wear Resistant Blade Materials

Tomas Grejtak, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN; Jeffrey Lacey, Miranda Kuns, Damon Hartley, David Thompson, Idaho National Laboratory, Idaho Falls, ID; George Fenske, Oyelayo Ajayi, Argonne National Laboratory, Lemont, IL; Peter Blau, Blau Tribology Consulting, Enka, NC

Critical components of biomass preprocessing equipment are susceptible to excessive wear due to inorganic components of feedstock. Through comprehensive characterization and in-depth analysis, we demonstrate that knife milling performance for preprocessing forest residue can be significantly improved by using specialized wear-resistant blade material. Experimental testing on a knife mill revealed that the operational life of milling knives can be improved by 8X and 3X with applying tungsten carbide and iron borided blades, respectively, in comparison to the commonly used tool steel blades. Additionally, the advanced blade material not only enhances the durability of knives but also increases the milling throughput and improves the operational cost of knife milling.

3907873: A Comparative Analysis in Tribo-Mechanical Behavior of Cold Rolled and Additively Manufactured Nickel Titanium Alloy

Hyunsuk Choi, Sougata Roy, University of North Dakota, Grand Forks, ND; Yashwanth Bandari, FasTech LLC, Danville, VA

NiTi is known for its two unique properties: shape memory and superelasticity. NiTi alloys with superelastic behavior are recently being studied for load-bearing applications due to their ability to withstand significant elastic strains and enhanced mechanical characteristics compared to shape memory NiTi. This research used ball-on-flat, reciprocating sliding tests to examine the tribo-mechanical behavior of a NiTi alloy fabricated via Laser wire directed energy deposition (LW-DED). The tests were carried out in unlubricated conditions against AISI 52100 balls at temperatures ranging from room temperature to 200°C. Wear tracks were analyzed using the sets of microscopy and white light interferometry to understand the changes in wear mechanisms as a function of testing temperature. These findings are then compared to the behavior of superelastic cold-rolled 55 NiTi alloy to reveal the benefits and challenges of fabricating NiTi alloy using LW-DED additive manufacturing.

3907838: Tribochemistry of Diamond-like Carbon – Interplay Between Hydrogen Content in the Film and Oxidative Gas in the Environment

Seokhoon Jang, Pennsylvania State University, State College, PA; Muztoba Rabbani, Ashlie Martini, University of California Merced, Merced, CA; Andrew Ogrinc, Maxwell Wetherington, Seong Kim, The Pennsylvania State University, University Park, PA

The superlubricity of hydrogenated diamond-like carbon (HDLC) solid lubricant films is highly sensitive to the hydrogen content in the film and the oxidizing gas in the environment. This study investigated the tribochemical origins of the environmental sensitivity of HDLC films with two different hydrogen contents (mildly-HDLC vs. highly-HDLC). A Langmuir-type kinetics analysis revealed that the highly-HDLC film exhibited lower oxidation propensity than the mildly-HDLC film in O_2 and H_2O environments. The molecular origin of such difference was investigated with reactive molecular dynamics simulations; the hydrogen content dependence of oxidation reactivity of HDLC with O_2 and H_2O may be governed by the degree of undercoordinated carbon atoms in the film which decreases as the degree of hydrogenation increases. This finding can guide the design of HDLC that is less sensitive to environmental conditions and exhibits superlubricity across a wider range of practical operating conditions.

3907831: An Investigation of Varnish Formation and Removal in a High-Pressure Piston Pump

Shriya Reddy Kalijaveedu, Fluid Power Institute, Milwaukee School of Engineering, Milwaukee, WI

Prevention and remediation of hydraulic system varnish is important to equipment users because varnish can cause valve malfunction, heat exchanger fouling and shorten fluid life. In this investigation the tendency of fluids to form deposits was evaluated using the JCMAS P 045 High Pressure Pump test. Fluids that had low and high varnish-forming potential were evaluated. A modular plate and frame heat exchanger was used to facilitate inspection and analysis of deposits. Fluids with high-varnish forming tendency were found to deposit oxidation debris on heat exchanger surfaces. Thermal imagine and heat transfer analysis were used to evaluate effect of varnish on heat exchanger performance. A varnish removing additive effectiveness was evaluated. The system was drained and disassembled for inspection. The cleaner was found be effective at removing deposits at both temperatures. These findings provide insights in how to extend the life of hydraulic fluids and equipment.

3811630: Molecular Dynamics Simulation and Machine Learning-assisted Analysis for Nano-confined Lubricants Under Slow Shear Rates Nearly Comparable to Experiments

Ikki Yasuda, Yusei Kobayashi, Katsuhiro Endo, Noriyoshi Arai, Kenji Yasuoka, Keio University, Yokohama, Japan; Kazuhiko Fujiwara, Kuniaki Yajima, National Institute of Technology, Sendai College, Sendai, Japan

Lubricant with the desired frictional properties is important in achieving an energy-saving society. At the interfaces of mechanical components, lubricants are confined under high shear rate and pressure, and behave quite differently from the bulk. To probe the molecular behavior, computational approaches such as non-equilibrium molecular dynamics (NEMD) simulations have been performed. However, the low-shear-velocity regions have rarely been simulated due to the expensive calculation, and the molecular dynamics around shear velocity comparable to the experiment are not clearly understood. In this study, we performed NEMD simulations of extremely confined lubricants, which were analyzed using an unsupervised machine learning approach to detect molecular movements that contribute to shear thinning. We found the magnitude of diffusion corresponded to the viscosity, and the location of slips that varied depending on the spherical and chain lubricants was irrelevant.

3906603: Effect of Chemical Cleaners on Varnish Removal and Elastomeric Seals

Jose Morales, Ashlie Martini, University of California, Merced, Winton, CA; Zhen Zhou, Chevron Global Lubricants, Richmond, CA

Varnish formation from lubricating oils is a challenge because the deposits on metal surfaces could obstruct fluid flow and result in wear or heat transfer issues. Chemical cleaners can remove varnish from the surfaces of lubricated mechanical components. Using a custom test rig, chemical cleaners specifically formulated to remove varnish were evaluated under different conditions. The testing procedure determined the rate of varnish removal and enabled quantitative comparison of cleaner performance. In addition, the potential effect of the cleaners to degrade elastomeric materials was evaluated by characterizing the geometric and mechanical properties of seals in the test rig. The results of this testing contribute to enabling mechanical systems to have a longer lifespan, proper functionality, and better performance.

3907064: Experimental and Finite Element Modeling of Soft Biological Tissues in Contact

Conor Shanley, Northwestern University, Evanston, IL

Development of novel medical devices for treatment of musculoskeletal pain at trigger points necessitates the modelling of contact between relatively rigid structural materials (e.g., acetal polymers) and soft tissues, such as skeletal muscle. The steady-state indentation response of the skeletal muscle structure of the posterior neck was measured with a testing device, and a finite element model (FEM) was built to simulate the response, using a first-order Ogden hyper-elastic solid material model. The error between empirical and FEM-generated displacement-load curves was minimized via a two-stage optimization process comprised of an Optimal Latin Hypercube DoE analysis and a Sequential Quadratic Programming optimization loop. The optimized Ogden model has an initial shear modulus ( ) of 5.16 kPa and a deviatoric exponent ( ) of 11.90. The results are similar to prior studies performed on in vitro tissue samples, but the new model parameters better reflect the in vivo tissue behavior.

3907069: Tribological Performance of Lithium Complex Greases with Pyrylium- and Pyridinium-Based Ionic Liquids

Cinderella Moustafa, Miguel Chacon Teran, Michael Findlater, Ashlie Martini, University of California, Merced, Merced, CA

Ionic Liquids (ILs) have been studied as green lubricants for the last two decades. Literature has shown that adding ILs to lubricating oils can have a positive effect on wear and friction behavior. However, there have been fewer studies about the potential benefit of ILs as additives for grease. In this study, the tribological performance of lithium complex greases with pyrylium- and pyridinium-based ILs were investigated. Four-ball tests according to ASTM D2266 and ball-on-disk tests according to a modified combination of ASTM G99 and ASTM D5907 standards were used to evaluate the friction coefficient and wear behavior of the greases. At least two trials were run for each grease-IL combination and test condition using different 52100 steel samples to ensure the results are robust. The results show that pyrylium- and pyridinium-based ILs can be effectively blended into lithium complex greases as additives and may enhance both wear and friction performance.

3907408: Molecular Dynamics Modeling of Thermal Conductivity of Several Hydrocarbon Base Oils

Jannat Ahmed, Q. Jane Wang, Oluwaseyi Balogun, Northwestern University, Evanston, IL; Ning Ren, Roger England, Frances Lockwood, Valvoline Inc., Lexington, KY

The research is on the determination of the thermal conductivities of several hydrocarbon base oils by means of non-equilibrium molecular dynamics simulation using two force-fields. It aims to explore a simulation-based method for lubricant molecular design and analysis concerning heat transfer in vehicle components. We used two methods to calculate bulk thermal conductivity, both giving consistent results. The predicted conductivities show certain overpredictions as compared with the experimentally measured results, and overprediction factors are defined. The results lead to a formula that describes the effects of carbon chain length and number of branches of liquid hydrocarbons on their thermal conductivity.

Early Career and Student Posters

3901772: Optimization of Digital Image Correlation Techniques for the Assessment of Plantar Loading and Tribology Regimes in Foot Health Applications

Francesca Sairally, Peter Culmer, University of Leeds, Leeds, United Kingdom; Claire Brockett, University of Sheffield, Sheffield, United Kingdom; Heidi Siddle, David Russell, School of Medicine, Leeds, United Kingdom

Diabetic foot ulceration is exacerbated by plantar loading patterns and leads to health complications. Current assessment includes pressure measurement but neglects shear, which contributes to ulcer formation. Our group developed a novel plantar load measurement technique (STAMPS) for clinical application. This combines a plastically deformable insole with Digital Image Correlation (DIC) to characterise in-shoe shear strain. This work reports DIC enhancement through computational methods to improve spatial resolution for assessing tribological interactions. A parametric study of DIC subset parameters was conducted against representative literature plantar strain. Experimental loaded deformation studies validated the outcomes. The results show reducing the DIC subset and strain radius improves the strain output accuracy, with larger settings showing over-smoothing. This technique shows potential for risk assessment in a clinical environment, such as diabetic foot interventions.

3902839: Tribological Behaviors of Textured Surfaces Produced by Laser Powder Bed Fusion

Tobias Martin, Q. Jane Wang, Jian Cao, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Surface texture affects the tribological behavior of mechanical components in boundary and mixed lubrication. Currently, many additively manufactured parts undergo expensive and time-consuming post processing to meet surface roughness requirements. If tribologically beneficial surface textures are designed so that the texturing and additive manufacturing processes can be combined, parts thus made can be used in their as-built condition. Consequently, production cost is reduced, and a prolonged life of these parts can be expected. This poster presents a study based on reciprocating tribotests, performed on the top surfaces of materials produced by laser powder bed fusion with the sliding direction parallel, perpendicular, and angled to the laser scanning direction. Friction and wear were recorded and correlated to the position within the wear track and velocity variation for an in-depth understanding of these parameters and their impact on the performance of surface texture patterns.

3901888: Tactile Perception of Vellum Quantified by Friction and Surface Roughness

Samuel Leventini, Brian Martin-Gutierrez, Abhishek Kumar, Ashlie Martini, University of California, Merced, Merced, CA; Asa Mittmann, CSU Chico, Chico, CA; Susan Kim, Illinois State University, Normal, IL

Before digital copies of books and manuscripts, they were written on vellum, or prepared skins of animals. Scientists today have proposed that ancient readers navigated through the papers by touch, or sensory responses from interacting with the medium. Here, we studied the potential correlation between sliding friction, measured roughness, and perceived roughness of vellum samples from different animals and preparation methods. Friction was measured through unilateral reciprocating sliding tests on 14 different samples with a probe mimicking a human finger. Roughness and other characteristics were measured using interferometry. A panel of untrained volunteers was used to gather sensory data for correlation with the other results. Results were then compared against each other to find any correlation or trends. Data demonstrated an inverse relationship between perceived and actual roughness, and coefficient of friction and measured roughness.

3903929: Molecular Structure and Environment Dependence of Shear-Driven Chemical Reactions

Yu-Sheng Li, Seokhoon Jang, Seong Kim, The Pennsylvania State University, State College, PA; Fakhrul Hasan Bhuiyan, Ashlie Martini, University of California, Merced, Merced, CA

This study examined the tribopolymerization of molecules with different internal ring strain energy (cyclohexane, cyclohexene, methylcyclopentane) on stainless steel surfaces in N_2, O_2, and H_2 environments to gain a better understanding of the underlying mechanisms of tribochemistry. The results showed that in N_2 and H_2 environments, cyclohexane had the lowest reactivity among the three precursors tested, with a similar trend observed in reactive molecular dynamics simulations. Additionally, the origin of D- and G- bands in the Raman spectrum of tribofilms could be a result of photochemical degradation of tribofims by high-energy Raman laser. Based on the infrared analysis, tribofilms were organic materials containing oxygenated groups. These findings provide valuable insights into the complex and dynamic interfacial processes involved in tribochemistry, which could have important implications for developing more effective lubricants and surface coatings for industrial applications.

3905567: A Review of the Variation of Physicochemical and Tribological Properties of Biolubricants Depending on its Chemical Structure

Claudia Sanjurjo Muñiz, Eduardo Rodríguez Ordóñez, Antolín Estaeban Hernández Battez, University of Oviedo, Gijón, Asturias, Spain

The increase in crude oil prices, the environmental consequences or the depletion of fossil resources, have increased the necessity of bio-based alternatives. This leads to the search for renewable, biodegradable and eco-friendly raw materials to obtain lubricants that meet these characteristics. This review deals with the state of the art of bio-lubricants along their most common raw materials and molecular structures, as well as the relationship between molecular structures and physicochemical/tribological properties. This research concludes that the production of fatty acid alkyl esters (FAAEs) from vegetable oils as the most promising route to produce a wide range of bio-lubricants through double transesterification reactions. In addition, the need to study its application in the production of microalgae-derived biol-lubricants is revealed, due to its environmental benefits during culture and production processes.

3904795: Metal Oxide Tribofilms: Relating Antiwear Additive Synergy with Mechanical Properties

Daniel Delghandi, Sage Fulco, Pranjal Nautiyal, Parker LaMascus, Kevin Turner, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Robert Wiacek, Pixelligent Technologies, Baltimore, MD

A reduction in gear and engine oil viscosity is a potential solution in the quest for a higher efficiency transportation sector, but lower viscosity oil requires advanced anti-wear additives. Zirconia nanocrystals form tribofilms that inhibit wear and scuffing while behaving cooperatively with commercial antiwear additives, suggesting that the antiwear additives may be integrated in the tribofilm, affecting its properties. This work investigates the mechanical properties of zirconia tribofilms formed with various concentrations of a phosphorus-based additive. Phosphorus integration is determined by spatially resolved compositional characterization, and nanoindentation is used to determine the mechanical properties of the formed tribofilms. We report that phosphorus can be integrated in the tribofilm bulk without influencing the hardness or elastic modulus of the tribofilm.

3905814: Run-In and Superlubricity of Diamond-Like Carbon at Microscale Sliding Contacts

Hind Flaih, Ana Colliton, Eskil Irgens, Lucas Kramarczuk, Griffin Rauber, Jordan Vickers, Brian Borovsky, St. Olaf College, Northfield, MN; Seokhoon Jang, Seong Kim, Pennsylvania State University, State College, PA; Zhenbin Gong, Junyan Zhang, Lanzhou Institute of Chemical Physics, Lanzhou, China

We present an experimental study of the run-in to low friction of diamond-like carbon (DLC) coatings through a process involving tribochemical reactions. We use an indenter probe to load a stainless-steel sphere (100 μm) onto a hydrogenated DLC coating that forms the surface of a quartz crystal microbalance (QCM). By resonating a shear mode of the QCM, we induce sliding friction at the interface with track lengths in the nanometer range and frequencies near 5 MHz. The QCM measures friction while the normal load is fixed at values between 5 μN and 1 mN. These measurements can be sustained even when a secondary lateral motion is superimposed using a piezo stage, with a track length of 20 μm and frequency of 10 Hz. Our results show that adding microscale sliding facilitates the run-in process to ultralow friction values, requiring far fewer cycles and less time than nanoscale sliding alone. We present measurements of the frictional shear stress showing a linear increase with pressure.

3905210: Molecular Dynamics Study of Thermal Degradation of Lubricants for Aerospace Applications

Daniel Miliate, Ashlie Martini, University of California Merced, Merced, CA; Stephen. Didziulis, Andrew Clough, Peter Frantz, The Aerospace Corporation, El Segundo, CA

The extreme conditions of space have created unique challenges in tribology. The development of multiply-alkylated cyclopentane (MAC) lubricants has been instrumental in addressing some of these challenges. However, experimental results have shown that lubricant life depends in part on the materials of the interreacting surfaces. The objective of this study was to use reactive molecular dynamics simulations to understand the degradation mechanisms of the MAC lubricant 1,3,4-tri-(2-octyldodecyl) cyclopentane. The lubricant was modeled in the presence of various metals commonly used in aerospace applications. Simulations were run at elevated temperatures both with and without oxygen to analyze the effect of the metal on oxidation and non-oxidative thermal degradation. The findings here contribute to better understanding MAC lubricant degradation mechanisms and its sensitivity to metals

3899176: Benchtop Tribological Characterization of Electric Motor Greases for Hybrid Bearings

Abhishek Kumar, Jose Vasquez-Reyes, Ashlie Martini, University of California Merced, Merced, CA; Christina Cheung, Thomas Murray, Anoop Kumar, Chevron Corporation, Richmond, CA

Electric motors (EM) can require that greases operate in demanding conditions, such as high temperature, and with non-ferrous materials. Evaluating grease formulations for these conditions therefore requires modifications of standard benchtop tests. This study involved tribological characterization of EM greases using four-ball and ball-on-disk tests with materials and conditions modified to better reflect current and emerging applications, including electric vehicles. The hybrid bearing configuration was mimicked by testing with silicon nitride and 52100 steel tribopairs. The market-available and new grease formulations studied had mineral or synthetic base oil, and polyurea or lithium thickener. The friction traces, wear response, energy dissipation, and estimated film thickness were analyzed to enable comparison of the tribological properties of these greases specifically for EM applications.

3808273: Towards Achieving Long Term Reliability in High-Performance Electroadhesive Clutches for Haptics and Robotics

Changhyun Choi, Aditya Kuchibhotla, Cynthia Hipwell, Texas A&M University, College Station, TX

To change friction force in various applications such as haptics and robotics, electroadhesion has been gaining attention due to its reduced complexity and fast response. Models which combine electric field and contact mechanics have been used to predict initial electrostatic force, such as in a electrostatic chuck, but they do not address dynamic or long term performance in devices which may have relative motion, such as clutches. These devices are more likely to have issues with wear and its longterm impact on friction force. In this work, we analyze the clutching performance between a conductive latex and dielectric substrate using electroadhesion and study its tribological behavior with respect to different operational, material, and geometric parameters. Understanding the failure modes will be used to further improve long-term clutching performance, achieving high electroadhesive shear stress and high wear resistance, which can enable the wider use of electroadhesion.

3832230: Wear-Related Fault Detection of Hydraulic Axial Piston Pump Using Deep Learning Model with Limited Data Samples

Chul-Hee Lee, Oybek Eraliev, Kwang-Hee Lee, Inha University, Incheon, Republic of Korea

Numerous studies of fault detection systems have demonstrated the advantage of DL models over classical machine learning (ML) in terms of feature extraction, feature dimension reduction, and diagnosis performance. Sometimes, a sensor problem during data acquisition renders some of the information potentially inappropriate for further processing, leaving only a small sample of the data available for analysis. To overcome this drawback, a DL model based on a stacked convolutional autoencoder (SCAE) model is developed in this study. This study outlines the creation of a time-frequency visual pattern recognition-based approach for hydraulic axial piston pump fault detection mostly caused by wear damages at the contact interfaces. The results show that, even with a little data sample, the suggested approach can give an outstanding diagnostic performance with over 99.5%. Additionally, when the data is noisy, the suggested model performs better at diagnosis than other DL models.

Early Career and Student Posters

3810966: Superior Macro-Scale Tribological Performance by the Synergetic Effect of Graphene Family Materials and Aqueous Glycerol in Self-Mated Steel Contacts

Irfan Nadeem, Mitjan Kalin, University of Ljubljana, Ljubljana, Slovenia

Reducing friction is an utmost concern in the modern world due to its great prospect to reduce energy consumption. Glycerol provides superlubricity in industrially relevant sliding contacts such as steel and diamond-like carbon (DLC). With growing interest in green lubricants, we studied the synergetic effect of graphene-based nanomaterials with aqueous glycerol for improved lubrication performance between self-mated steel contacts. The results show that the aqueous glycerol with graphene based nanoadditves show superior dispersion stability and significantly reduced the friction and wear. This striking decrease in the coefficient of friction and wear is due to the synergetic effect of aqeous glycerol and graphene layers. This work demonstrated that graphene based green nano lubricants have a great potential to replace conventional environment polluting lubricants and paved the way for further investigation to get a deep insight into active lubrication mechanisms.

3812585: Modeling and Analysis of Piston-Pin Lubrication for Internal Combustion Engines Considering Deformation and Cavitation

Zhiyuan Shu, Zhen Meng, Tian Tian, Massachusetts Institute of Technology, Cambridge, MA; Rolf-Gerhard Fiedler, MAHLE International GmbH, Stuttgart, Germany; Per Liljeros, Volvo Penta, Gothenburg, Sweden

In an internal combustion engine system, the wrist pin operates under high pressure and temperature and is susceptible to friction and wear but the study on these tribological pairs proves to be difficult. In this work, a piston pin model is developed to simulate the flow field and interaction between the piston pin and the surfaces in contact with it. The influence of pressure and temperature on lubricating oil properties and surface deformation is considered. The simulation results applying the pin model to a diesel engine show that the flow of lubricating oil is easily affected by factors such as piston pin bore profile and lubricating oil supply. The key to reduce friction loss is to transport lubricating oil to high load area in time and to minimize local asperity contact by modifying the shape of pin bore and small end at the edges.

3833902: Analytical Study of Friction Reduction Performance for DLC-involving Contact with Commercial Fully-Formulated Oil

Maria-Isabel De Barros Bouchet, Yue Guan, Fabrice Dassenoy, Ecole Centrale de Lyon, Ecully, France

Diamond-like carbon (DLC) has become attractive in automobile industry thanks to its excellent anti-wear and low friction properties. For example, by tuning the mechanical properties of coatings, tetrahedral amorphous (ta-C) DLC self-mated configuration can reach ultralow friction regime with the presence of ZDDP [1]. Amorphous hydrogenated (a-CH) DLC self-mated configuration can also have CoF around 0.02 with PAO, but CoF increases with the presence of ZDDP additive [2]. However, in most of these works, the selected lubricants are mainly composed of a base oil + one/two additives, conditions far from the industrial application. In this work, the interaction of commercially fully-formulated oil with DLC self-mated and DLC/steel mixed configurations is investigated. The different parameters as sliding velocity, contact pressure are tuned to investigate their impact on tribological behaviour.

3835471: Applied Variational Methods for Modelling Vascular Structures

Abdu Yearwood, University of The West Indies, Georgetown, Guyana

This study applied variational methods within a level-set framework for the modeling of vascular structures. Extracting meaningful information from medical images was demonstrated using a DICOM dataset acquired from the OSIRIX online Library and the St. Joseph Mercy Hospital, Georgetown, Guyana. It was found that although active contouring could be used to reconstruct the surface of a segmented region by explicit definitions the reconstructed surface may not be a true representation of the vessel wall across all 2D images. Consequently, an implicit approach was applied to extract 3D structures, while a Chan-Vese model was used in a 2D context for a global understanding of the segmentation problem. While active contouring can often lead to poor performance, due to pixel leakage artifacts, it may yet prove useful as part of a pipeline to conduct realistic biofluid research.

3836553: Novel Fretting-Corrosion Mechanisms of Friction Stir Processed Steel Manufactured by High Deposition Rate Additive Manufacturing Process

Alessandro Ralls, Pradeep Menezes, University of Nevada, Reno, Reno, NV

Acting as a novel technology, the application of high-pressure deposited (HPD) coatings has attracted to attention of many due to its solid-state deposition-like features. From an industrial perspective, the application of HPD coatings is fundamental to preserving the working lifespans of various machining components. This is especially true in chloride-rich environments that are continuously exposed to oscillatory contacting tangential movements. However, due to the porous nature of HPD coatings, they suffer from rapid material degradation due to severe pitting and premature brittle fracture. In this work, we investigated the influence of FSP on the fretting-corrosion mechanisms of HPD steel. It was found that the effect of FSP enhanced the metallurgical bonding and intrinsic hardness of the HPD coating. As such, their fretting-corrosion performance was also improved, concluding that FSP is a viable method to enhance the surface quality of HPD coatings.

3895186: Investigating the Tensile and Compressive Properties of Diabetic and Non-Diabetic Plantar Skin to Develop Surrogates for Use in Biofidelic Tribological Test Beds

Sarah Crossland, Francesca Sairally, Jen Edwards, Peter Culmer, University of Leeds, Leeds, West Yorkshire, United Kingdom; Claire Brockett, University of Sheffield, Sheffield, United Kingdom

Diabetic foot ulceration (DFU) is a leading cause of non-traumatic lower limb loss with plantar loading, pressure and shear, contributing to formation. Current assessment tools are solely pressure based, further understanding of ulcer formation requires measurement of plantar shear load. Biofidelic testing using surrogates allows investigation of plantar skin and subcutaneous tissue strain responses under varied loading regimes reducing cadaveric tissue reliance. To develop representative surrogates, cadaveric plantar skin studies were conducted including stress-strain response and dynamic mechanical analysis for tensile and compressive properties using replicative frequencies and strains from the feasibility study. Surrogates were manufactured to mimic the cadaveric tissue response, using a silicone tissue with embedded strain limiting layer. The surrogates provide a repeatable method for use in tribological testing of the plantar aspect and detailed measurement of plantar loading.

3900395: Molecular Mechanisms of Tribochemical Reactions: Reactive Molecular Dynamics Simulations of Cyclic Organic Molecules

Fakhrul Hasan Bhuiyan, Ashlie Martini, University of California, Merced, Merced, CA; Yu-Sheng Li, Seong Kim, The Pennsylvania State University, State College, PA

Tribochemical reactions determine the performance of lubricant additives that form friction and wear-reducing tribofilms. However, mechanistic understanding of these reactions is still limited because the mechanochemical response of reactant species is a complex function of many variables. Here, we studied tribochemical reactions of simple cyclic organic molecules to isolate the effect of chemical structure on reaction yield and pathway. Results identified shear stress as the key driver of association reactions under tribological conditions. The trend of reaction yield in simulations was consistent with shear-driven polymerization yield in ball-on-flat sliding experiments. Analyzing the simulated oxidative chemisorption showed the effect of the chemical features of a reactant on its sensitivity to mechanochemical activation. Lastly, the most common association reaction pathways were identified, and a bond-by-bond analysis revealed the role of shear stress in mechanochemical activation.

3895265: A Multiscale Modeling Approach to Study the Plunger-Bore Interface of a Radial Plunger Pump

Henry Soewardiman, David Pickins, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Blake Johnson, Nikhil Murthy, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Within a high-pressure fuel pump, the plunger-bore interface is critical to ensure the efficient delivery of fuel to the rest of the fuel system. However, scuffing may occur at this interface due to high pressure, high-frequency motion, and poor lubrication. This poster presents a multiscale modeling system of a radial plunger pump to simulate the plunger motion and interaction with the cylinder bore, aiming to characterize the interfacial conditions that lead to severe adhesive wear. System-scale models identify the structural and fluid behavior of the fuel pump, and data from those models are used in a plunger-bore interface model to explore critical contact conditions in detail, particularly regions of asperity contact and the variation in the fuel charge-discharge cycle. The interface model then records the minimum film thickness, friction force variation, and leakage as factors for design optimization.

3931863: Superlubric Phase of Ice

Arnab Neogi, Subramanian SKRS Sankaranarayanan, University of Illinois, Chicago, IL; Anirudha Sumant, Argonne National Laboratory, Lemont, IL

We developed a machine learning potential which captures the interactions between two water molecules. With this force field being able to describe the properties of water, we modelled a tribology set up and discovered a superlubric regime for ice. The structure at the interface, which is formed by applying a specific normal load, temperature and sliding velocity have not been previously discovered and it is a metastable structure. This structure also falls under smart material, as this is not a thermodynamically stable structure on its own but is formed with the application on pressure-temperature-velocity conditions which means that the 2D layer is not depleted over long cycle range as long as the environmental conditions are maintained.

This discovery will lead us in fundamental understanding of the structural modifications that happen due to shearing and sliding on earth due to global atmosphere heating and other phases of ice that exist in other planetery bodies.

3918449: Stopper Contact During Freeze-Thaw Cycling of Prefilled Syringes

Catherine Fidd, Grace Lin, Adam DeLong, Kylie Van Meter, Santiago Lazarte, Florida State University, Tallahassee, FL; Nestor Rodriguez, Becton Dickinson, Franklin Lakes, NJ; Brandon Krick, Florida State University, Tallahassee, FL

Drugs and vaccines in prefilled syringes can be frozen for storage to maintain viability. Thermal-induced density and phase changes can result in stopper movement within the syringe barrel. Loss of contact with the stopper and barrel may occur due to the mismatch of thermal expansion coefficients and low-temperature phase transformations of the materials in the syringe system. The combined effects can result in hysteresis in the temperature-stopper displacement relationship; here, the stopper's final position at room temperature is different from the initial position after freeze-thaw cycles. This project aims to investigate the stopper displacement and contact via a cryostat system that can perform variable cooling/heating ramps from ambient down to -80°C. Realtime in situ optical imaging can track the stopper's movement during the freeze/thaw cycles, obtain CTEs of the syringe and stopper materials, and monitor barrel-stopper contact can be through differential pressure measurements.