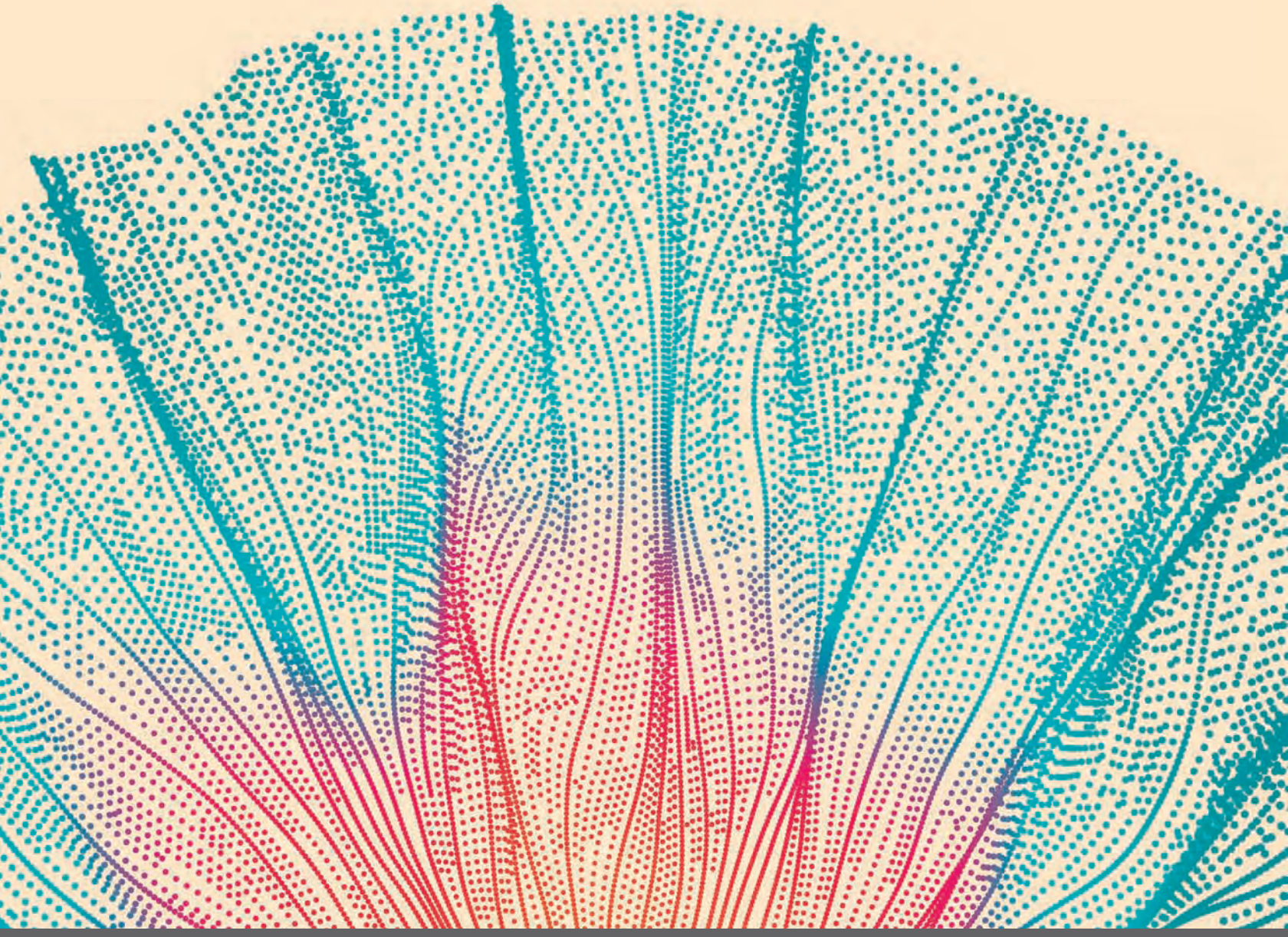
77th STLE Annual Meeting & Exhibition **May 21-25, 2023**

Long Beach Convention Center | Long Beach, California (USA)

Program Guide and Schedule

- Technical Sessions
- Exhibitors
- Education Courses
- Commercial Marketing Forum
- Student Poster Competition
- Keynote Session – “Hydrogen is Here: Are You Ready?
- Special Events
- Networking Opportunities



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The 2023 STLE Annual Meeting & Exhibition is sponsored by the Society of Tribologists and Lubrication Engineers, an international organization headquartered at 840 Busse Highway, Park Ridge, Illinois (USA) 60068-2376. Telephone: (847) 825-5536. Fax: (847) 825-1456. Email: **information@stle.org**. Web: **www.stle.org**. **STLE is a not-for-profit professional society founded in1944 to advance the science of tribology and best practices in lubrication engineering.**

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stle
LONG BEACH
May 21-25, 2023

Message from the President

Hello STLE Members, Friends and Guests,

We're glad to gather the STLE community again for our **77th Annual Meeting & Exhibition** in sunny California!

Two key STLE committees, the **Annual Meeting Program Committee** and the **Education Committee** should be applauded for their efforts in putting together a fantastic technical program featuring more than **500 paper presentations.** You can look forward to an outstanding week of professional development here in Long Beach, which is quickly becoming a popular convention and tourist destination with its scenic views of the Pacific Ocean and stunning beaches, restaurants and other notable attractions. All Annual Meeting events are conveniently located in the Long Beach Convention Center.

In addition to the technical sessions, the meeting features **11 one-day education courses** (offered on Sunday, Wednesday and Thursday) and the popular **Commercial Marketing Forum,** where the lubricant industry's most innovative companies discuss their latest products and services.

Don't forget to check out the **trade show** and visit with nearly 120 companies displaying the newest technologies, products and services. The exhibit hall is completely sold out, as this is an opportunity to engage with the industry's leading companies that are looking to do business with you. Also, you are invited to attend the **Exhibitor Appreciation Hour,** with two hours of dedicated exhibit time on Monday and Tuesday (3:00 pm – 4:00 pm). Refreshments will be served, and the trade show is the only annual meeting activity conducted at that time.

Remember, too, to take advantage of the social events, including the **Networking Reception** Monday evening at 6:30 pm and the **President's Luncheon** at 12:00 pm on Tuesday afternoon. Come connect with the entire STLE community, as we recognize this year's award recipients and the society's top volunteers who generously have donated their time and services to create new programs for all of us involved in the science of tribology and the practice of lubrication engineering.

To help navigate your investment and time here in Long Beach, please use this convenient **Program Guide** to help you prepare in advance and also make sure to download the free STLE Mobile App (available for iOS and Android devices). The app will have the most up to date annual meeting information throughout the week.

Additionally, all Annual Meeting attendees can also purchase the digital proceedings of the technical presentations that will be available after the meeting for a reduced fee, so you can catch up on any presentations you might have missed or would like to revisit again. For more information, visit **www.stle.org/AMproceedings**.

As you'll see on the following pages, STLE's 2023 Annual Meeting & Exhibition offers an unparalleled opportunity to discover technical concepts and make personal contacts that will help you save money for your organization and better serve your customers.

Lastly, if you are not already an STLE member, I would like to personally invite you to consider joining the leading technical organization for lubrication professionals. You'll soon find our membership cuts across a wide range of technical backgrounds and industries representing all segments of the tribology and lubrication field, who strongly embrace STLE's commitment to diversity and inclusion.

Have a wonderful week in Long Beach and enjoy the conference!

Ryan

Ryan Evans, Ph.D.
2022-2023 STLE President
The Timken Company

Preliminary as of April 25, 2023 – Subject to change.

2023 STLE Annual Meeting

Program schedule at a glance

Sunday, May 21

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Education Course Speakers Breakfast
7:00 am – 7:45 am – **Grand Ballroom**

Education Courses* (8:00 am – 5:00 pm)

- Advanced Lubrication 301: Advanced Additives – **104B**
- Basic Lubrication 101 – **102C**
- Gears 101 – **102B**
- Hydraulics 201: Hydraulic Fluids and Systems Overview – **101A**
- Metalworking Fluids 130: Metal Treatment Chemical – **101B**
- Sustainability: Biolubricants and Biofuels **(New!)** – **104A**
- Synthetics: Basics & Applications **(New!)** – **102A**

Refreshment Break
10:00 am – 10:30 am – **Foyer**

STLE New Member & Student Networking Reception
6:30 pm – 8:00 pm – **Bogarts & Co.**

Monday, May 22

Registration
6:30 am – 6:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Technical Sessions (8:00 am – 10:00 am)

- 1A • Lubrication Fundamentals I: Forecasting Trends – **101A**
- 1B • Rolling Element Bearings I – **101B**
- 1C • Sustainable Power Generation I – **102A**
- 1D • Materials Tribology I – **102B**
- 1E • Condition Monitoring I – **102C**
- 1G • Nonferrous Metals I – **103B**
- 1H • Commercial Marketing Forum I – **103C**
- 1I • Electric Vehicles I – **104A**
- 1K • Metalworking Fluids I – **201A**
- 1M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling I – **202A**
- 1N • Nanotribology I – **202B**
- 1O • AI and Machine Learning I – **202C**

2023 STLE Annual Meeting

Program schedule at a glance

Monday, May 22 | continued

Refreshment Break
10:00 am – 10:30 am – **Grand Ballroom Foyer**

Opening General Session (10:30 am – 12:00 pm)
Keynote Address – **Grand Ballroom 1/2**

- **"Hydrogen is Here: Are You Ready?"**
  Speaker: Angel Wileman, Manager, Thermofluids, Southwest Research Institute (SwRI)

Lunch (on your own) – 12:00 pm – 1:30 pm

Commercial Exhibits and Student Posters
12:00 pm – 5:00 pm – **Hall B**

Technical Sessions (1:30 pm – 6:00 pm)

- 2A • Lubrication Fundamentals II: Marine Engines – **101A**
- 2B • Rolling Element Bearings II – **101B**
- 2C • Wind Turbine Tribology I – **102A**
- 2D • Materials Tribology II – **102B**
- 2E • Condition Monitoring II – **102C**
- 2F • Environmentally Friendly Fluids I – **103A**
- 2G • Nonferrous Metals II – **103B**
- 2H • Commercial Marketing Forum II – **103C**
- 2I • Electric Vehicles II – **104A**
- 2K • Metalworking Fluids II – **201A**
- 2M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling II – **202A**
- 2N • Nanotribology II – **202B**
- 2O • AI and Machine Learning II – **202C**

Exhibitor Appreciation Break
3:00 pm – 4:00 pm – **Hall B**

Networking Reception
6:30 pm – 8:00 pm – **Hyatt Hotel**

Tuesday, May 23

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Commercial Exhibits and Student Posters
9:30 am – 12:00 pm & 2:00 pm – 5:30 pm – **Hall B**

Refreshment Break
10:00 am – 10:30 am – **Hall B**

Technical Sessions (8:00 am – 12:00 pm)

- 3A • Lubrication Fundamentals III: Friction Modifiers – **101A**
- 3B • Rolling Element Bearings III – **101B**
- 3C • Fluid Film Bearings I – **102A**
- 3D • Materials Tribology III – **102B**
- 3E • Condition Monitoring III – **102C**
- 3F • Environmentally Friendly Fluids II – **103A**
- 3G • Gears I – **103B**
- 3H • Commercial Marketing Forum III – **103C**
- 3I • Electric Vehicles III – **104A**
- 3K • Metalworking Fluids III – **201A**
- 3N • Nanotribology III – **202B**

President's Luncheon/Business Meeting
12:00 pm – 2:00 pm – **Grand Ballroom**

Technical Sessions (2:00 pm – 6:00 pm)

- 4A • Lubrication Fundamentals IV: Polymers – **101A**
- 4B • Rolling Element Bearings IV – **101B**
- 4C • Fluid Film Bearings II – **102A**
- 4D • Materials Tribology IV – **102B**
- 4F • Environmentally Friendly Fluids III – **103A**
- 4G • Gears II – **103B**
- 4H • Commercial Marketing Forum IV – **103C**
- 4I • Electric Vehicles IV – **104A**
- 4K • Metalworking Fluids IV – **201A**
- 4L • Tribochemistry I – **201B**
- 4N • Nanotribology IV – **202B**

Exhibitor Appreciation Break
3:00 pm – 4:00 pm – **Hall B**

Ideation Event: Roundtable Discussions
4:00 pm – 6:00 pm – **Grand Ballroom 1/3**

2023 STLE Annual Meeting

Program schedule at a glance

Wednesday, May 24

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Commercial Exhibits and Student Posters
9:30 am – 12:00 pm – **Hall B**

Refreshment Break
10:00 am – 10:30 am – **Hall B**

Education Courses* (8:00 am – 5:00 pm)

- Advanced Lubrication 302: Advanced Lubrication Regimes – **Regency DEFH (Hyatt Hotel)**
- Basic Lubrication 102 – **Regency A (Hyatt Hotel)**
- Metalworking Fluids 250: Understanding and Controlling Metal Removal – **Regency BC (Hyatt Hotel)**

Technical Sessions (8:00 am – 12:00 pm)

- 5A • Lubrication Fundamentals V: Wear and Engines – **101A**
- 5B • Rolling Element Bearings V – **101B**
- 5D • Materials Tribology V – **102B**
- 5E • Tribochemistry II – **102C**
- 5F • Contact Mechanics I – **103A**
- 5G • Tribotesting I – **103B**
- 5H • Commercial Marketing Forum V – **103C**
- 5I • Electric Vehicles V – **104A**
- 5L • Surface Engineering I – **201B**
- 5M • Grease I – **202A**
- 5N • Nanotribology V – **202B**

Lunch (on your own) – 12:00 pm – 1:30 pm

Technical Sessions (1:30 pm – 6:00 pm)

- 6A • Lubrication Fundamentals VI: Innovative Test Methods – **101A**
- 6B • Rolling Element Bearings VI – **101B**
- 6C • Synthetic Lubricants and Hydraulics I – **102A**
- 6D • Materials Tribology VI – **102B**
- 6E • Tribochemistry III – **102C**
- 6F • Contact Mechanics II – **103A**
- 6G • Tribotesting II – **103B**
- 6H • Commercial Marketing Forum VI – **103C**
- 6I • Electric Vehicles VI – **104A**
- 6K • Tribology of Biomaterials I – **201A**
- 6L • Surface Engineering II – **201B**

Technical Sessions | continued

- 6M • Grease II – **202A**
- 6N • Wear I – **202B**

Refreshment Break
3:00 pm – 3:30 pm – **Foyer**

Thursday, May 25

Registration
6:30 am – 12:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Education Courses* (8:00 am – 5:00 pm)

- Electric Vehicles – **104A-B**

Technical Sessions (8:00 am – 12:00 pm)

- 7A • Lubrication Fundamentals VII: Nanoparticles and Coatings – **101A**
- 7C • Seals I – **102A**
- 7E • Tribochemistry IV – **102C**
- 7F • Biotribology I – **103A**
- 7G • Tribotesting III – **103B**
- 7H • Commercial Marketing Forum VII – **103C**
- 7I • Electric Vehicles VII – **104A**
- 7J • Metalworking Fluids V – **201A**
- 7K • Surface Engineering III – **201B**
- 7L • Grease III – **202A**
- 7M • Wear II – **202B**

Refreshment Break
10:00 am – 10:30 am – **Foyer**

Lunch (on your own) – 12:00 pm – 1:30 pm

Technical Sessions (1:30 pm – 6:00 pm)

- 8C • Seals II – **102A**
- 8F • Biotribology II – **103A**
- 8G • Tribotesting IV – **103B**
- 8I • Electric Vehicles and Engine and Drivetrain VIII – **104A**
- 8L • Grease IV – **202A**
- 8M • Wear III – **202B**

Refreshment Break
3:00 pm – 3:30 pm – **Foyer**

2023 STLE Annual Meeting

Technical sessions index

Monday, May 22

Technical Sessions (8:00 am – 10:00 am)

Technical Sessions (1:30 pm – 6:00 pm)

Tuesday, May 23

Technical Sessions (8:00 am – 12:00 pm)

Technical Sessions (2:00 pm – 6:00 pm)

Ideation Event: Roundtable Discussions
(4:00 pm – 6:00 pm)

2023 STLE Annual Meeting

Technical sessions index

Wednesday, May 24

Technical Sessions (8:00 am – 12:00 pm)

Technical Sessions (1:30 pm – 6:00 pm)

Thursday, May 25

Technical Sessions (8:00 am – 12:00 pm)

Technical Sessions (1:30 pm – 6:00 pm)

Education courses index

Education Courses* – (8:00 am to 5:00 pm)

Sunday, May 21

Wednesday, May 24

Thursday, May 25

**Rooms subject to change.*

2023 STLE Annual Meeting

Business meetings schedule

Technical Committees

Monday, May 22

Session 2G • Room 103B
Nonferrous Metals (4:30 pm – 5:30 pm)

Session 2E • Room 102C
Condition Monitoring (5:30 pm – 6:00 pm)

NEW!
Session 2C • Room 102A
Sustainable Power Generation (5:30 pm – 6:00 pm)

Session 2C • Room 102A
Wind Turbine Tribology (5:30 pm – 6:00 pm)

Tuesday, May 23

Session 4G • Room 103B
Gears (4:00 pm –4:30 pm)

Session 4F • Room 103A
Environmentally Friendly Fluids (5:00 pm –5:30 pm)

Session 4N • Room202B
Nanotribology (5:00 pm – 6:00 pm)

Session 4C • Room 102A
Fluid Film Bearings (5:30 pm – 6:00 pm)

Session 4A • Room 101A
Lubrication Fundamentals (5:30 pm – 6:00 pm)

Session 4K • Room 201A
Metalworking Fluids (6:00 pm – 6:30 pm)

Session 4B • Room 101B
Rolling Element Bearings (6:00 pm – 6:30pm)

Wednesday, May 24

Session 6M • Room 202A
Grease (4:30 pm – 5:30 pm)

Session 6L • Room 201B
Surface Engineering (5:00 pm – 5:30 pm)

Session 6N • Room 202B
Wear (5:00 pm – 5:30 pm)

Session 6D • Room 102B
Materials Tribology (5:00 pm – 5:30 pm)

Session 6K • Room 201A
Biotribology (5:30 pm – 6:00 pm)

Session 6G • Room103B
Tribotesting (5:30 pm – 6:00 pm)

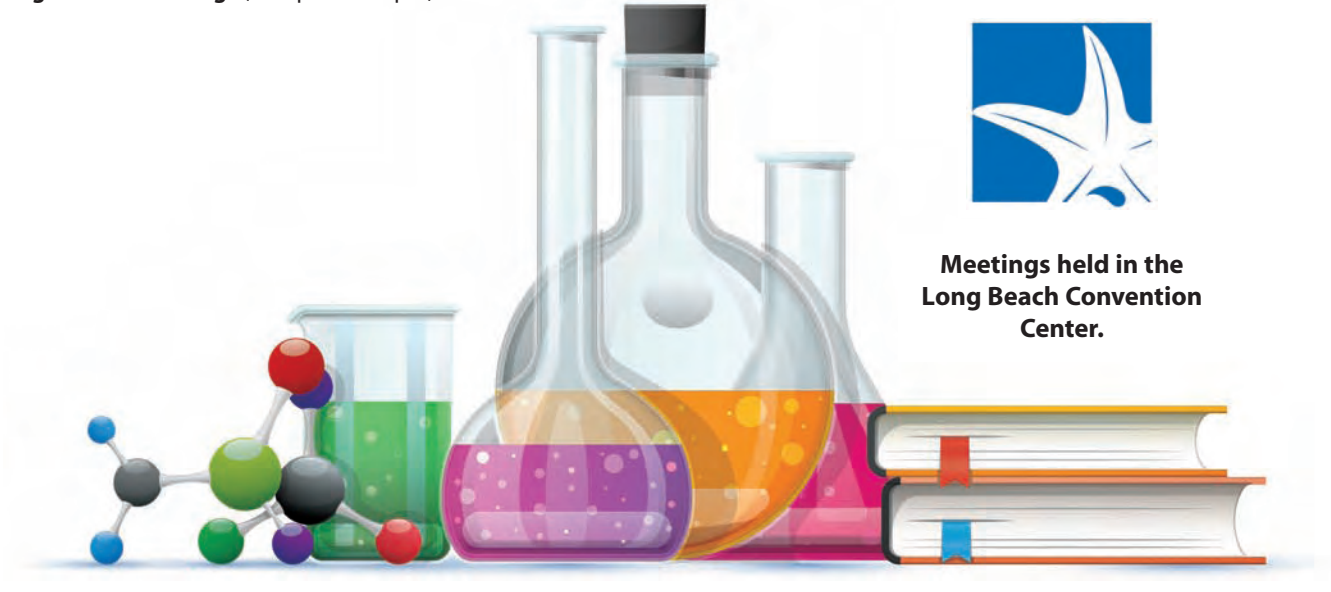
Session 6F • Room103A
Contact Mechanics (6:00 pm – 6:30 pm)

Session 6I • Room 104A
Electric Vehicles/Engine & Drivetrain (6:00 pm – 6:30 pm)

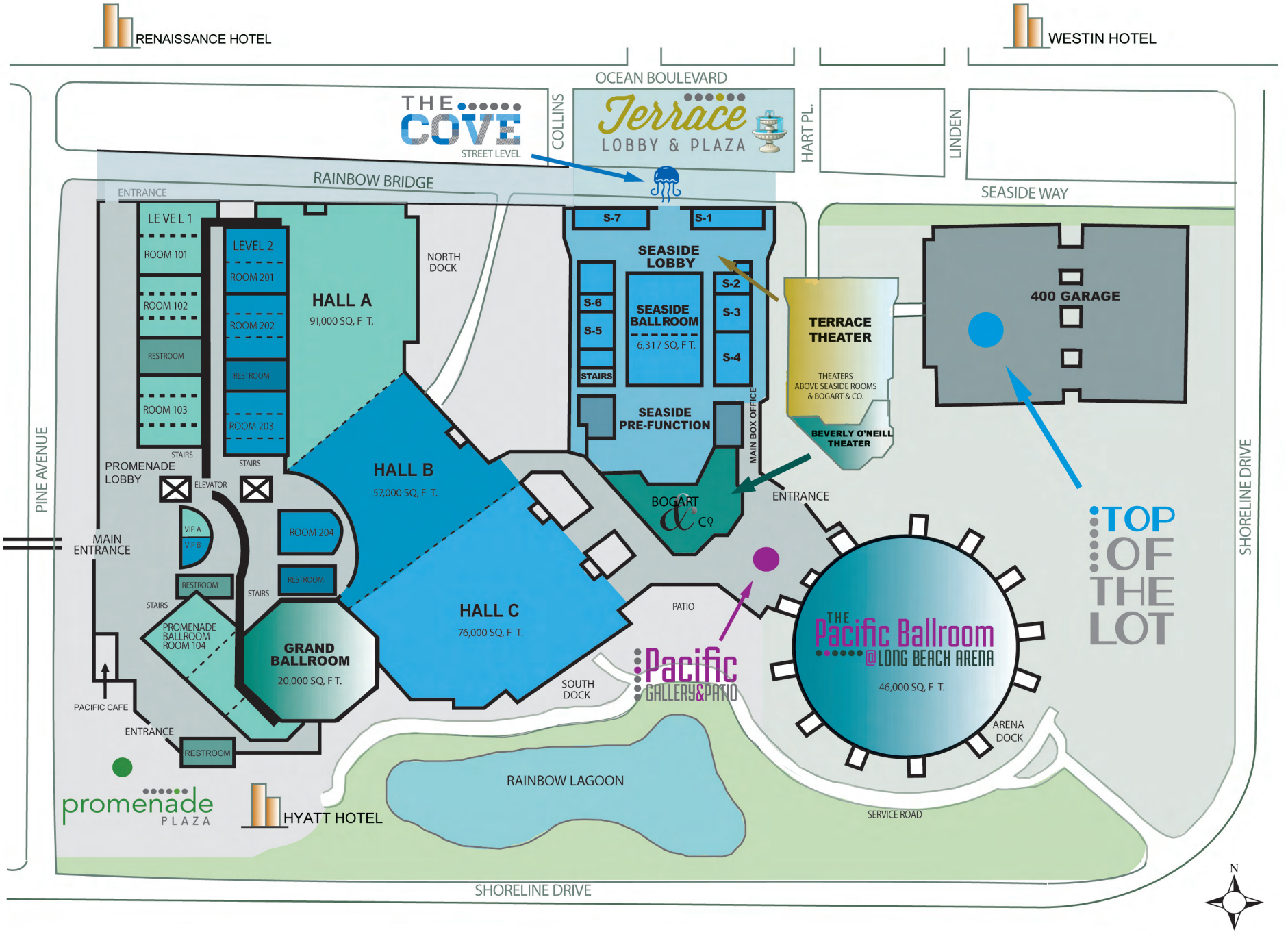
Session 6C • Room 102A
Synthetic Lubricants & Hydraulics (6:00 pm – 6:30 pm)

Thursday, May 25

Session 8C • Room 102A
Seals (5:00 pm – 5:30 pm)



Meetings held in the Long Beach Convention Center.


RENAISSANCE HOTEL
WESTIN HOTEL
OCEAN BOULEVARD
THE COVE
STREET LEVEL
COLLINS
Terrace
LOBBY & PLAZA
HART PL.
LINDEN
RAINBOW BRIDGE
ENTRANCE
SEASIDE WAY
LEVEL 1
ROOM 101
ROOM 102
RESTROOM
ROOM 103
STAIRS
LEVEL 2
ROOM 201
ROOM 202
RESTROOM
ROOM 203
STAIRS
HALL A
91,000 SQ. F T.
NORTH DOCK
S-7
S-1
SEASIDE LOBBY
S-6
S-5
STAIRS
SEASIDE BALLROOM
6,317 SQ. F T.
S-2
S-3
S-4
SEASIDE PRE-FUNCTION
MAIN BOX OFFICE
TERRACE THEATER
THEATERS ABOVE SEASIDE ROOMS & BOGART & CO.
BEVERLY O'NEILL THEATER
400 GARAGE
PINE AVENUE
PROMENADE LOBBY
ELEVATOR
HALL B
57,000 SQ. F T.
BOGART & Co
ENTRANCE
SHORELINE DRIVE
MAIN ENTRANCE
VIP A
VIP B
ROOM 204
RESTROOM
RESTROOM
STAIRS
STAIRS
PROMENADE BALLROOM ROOM 104
GRAND BALLROOM
20,000 SQ. F T.
HALL C
76,000 SQ. F T.
PATIO
TOP OF THE LOT
Pacific
GALLERY & PATIO
THE Pacific Ballroom
@LONG BEACH ARENA
46,000 SQ. F T.
SOUTH DOCK
PACIFIC CAFE
ENTRANCE
RESTROOM
ARENA DOCK
promenade
PLAZA
HYATT HOTEL
RAINBOW LAGOON
SERVICE ROAD
SHORELINE DRIVE
N

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LONG BEACH
May 21-25, 2023

Annual meeting exhibitors

The exhibition is located in the Long Beach Convention Center – Hall B.

Company Name	Booth #
Acme-Hardesty Company	411/413
ADEKA USA Corporation	717
Advanced Chemical Concepts Inc.	227
Agilent Technologies	810
Amee Castor & Derivatives Ltd.	617
American Petroleum Institute	715
American Refining Group	814
AnalytiChem	818
Analytik Jena US	630
Anhui Trust Chem Co., Ltd.	322
Applied Rigaku Technologies	531
Ayalytical Instruments	323/325
Barentz North America, LLC	618
Baron USA, LLC	719
BASF	316/318
Biosynthetic Technologies	521
Bruker	119/121
BYK USA	631
Cannon Instrument Company	127
Cargill	730
Carpenter Company	331
ChemCeed	713
Chevron Phillips Chemical Company	320
Clariant	624/626
Colonial Chemical Inc.	224/226
Compass Instruments	710/712
DataPhysics Instruments USA	820
DC Scientific	725/727
DL Chemical	816
Dover Chemical Corporation	327
Dow	523
Eastman Chemical Company	610
Elé Corporation	321
Elemental Scientific	718
Emery Oleochemicals	424/426
ENEOS USA, Inc.	612/614
Ergon, Inc.	216/218
Evonik Oil Additives USA, Inc.	205
ExxonMobil Chemical Company	211
Falex Corporation	714
FedChem/Federal Process	421
Formulaction	423
Functional Products, Inc.	623
Gehring-Montgomery, Inc.	625/627
GELITA	720
Huntsman	516
IMCD US	417/419
Indorama	530
Industrial Quimica Lasem S.A.U.	324/326
Ingevity	431
INEOS Oligomers	510/512
Italmatch Chemicals	311/313
Kao Chemicals Europe, S.L.U.	223
KH Neochem Americas, Inc.	619
King Industries, Inc.	217/219
Koehler Instrument Company, Inc.	410/412
Korea Institute of Science and Technology (KIST)	822
LANXESS Corporation	511/513
LGC Standards	826
LSI Chemical	621
Lubricant Expo	830
Münzing	220
Napoleon Engineering Services	123
Nouryon	711
Oil Filtration Systems	616
Optimol Instruments Pruftechnik GmbH	420
ORG Chem Group	709
Palmer Holland Inc.	231/330
PCC Chemax, Inc.	613
PCC Rokita	615
PCS Instruments	515/517/519
PerkinElmer	125
Phoenix Tribology Ltd.	230
Pilot Chemical Company	422
Ravago Chemicals North America	111
Rianlon Americas, Inc.	721
Richful Lube Additive Co., Ltd.	303
Rtec Instruments	620/622
Sanyo Chemical	430
Sasol Chemicals	524/526
Savant Labs	520
Sea-Land Chemical Company	221
SI Group	731
Soltex, Inc.	222
Solvay USA	716
SONGWON International – Americas Inc.	225
TAMU-MEEN	824
Tannas Company & King Refrigeration	522
The Lubrizol Corporation	317/319
Tulstar Products, Inc.	722
Turbomachinery Laboratory	812
UniSource-Energy, LLC	723
United Soybean Board	131
Univar Solutions	416/418
Vanderbilt Chemicals, LLC	117
VBase Oil Company	726
Wincom, Inc.	724
Zschimmer & Schwarz	611

*The above exhibitors are displaying the lubricant industry's latest products, services and technologies at the **2023 STLE Annual Meeting & Exhibition.** This list is complete as of April 25, 2023.*

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Long Beach Convention Center Exhibit Hall

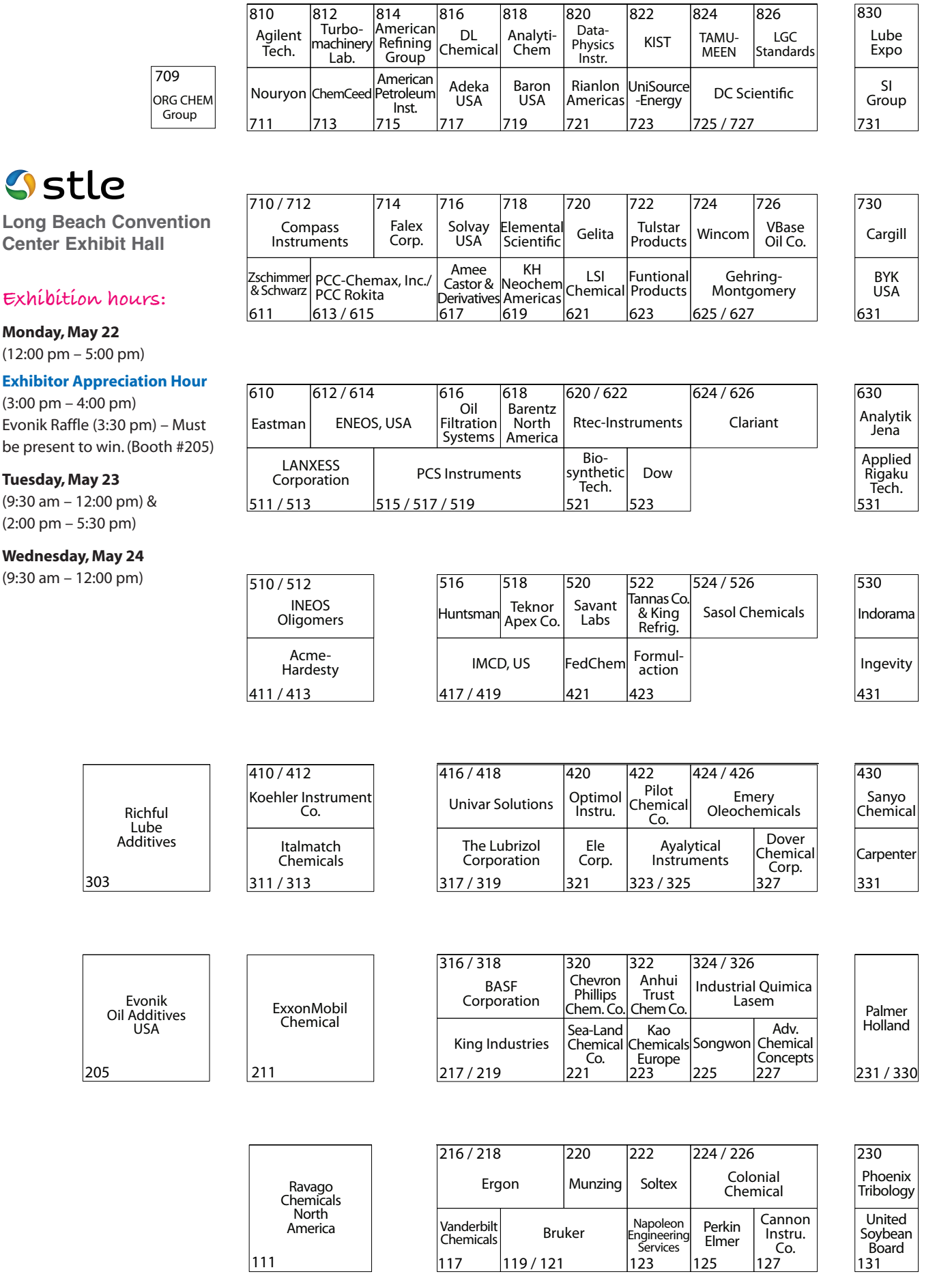
Exhibition hours:

Monday, May 22
(12:00 pm – 5:00 pm)

Exhibitor Appreciation Hour
(3:00 pm – 4:00 pm)
Evonik Raffle (3:30 pm) – Must be present to win. (Booth #205)

Tuesday, May 23
(9:30 am – 12:00 pm) &
(2:00 pm – 5:30 pm)

Wednesday, May 24
(9:30 am – 12:00 pm)



Annual meeting sponsors

*STLE wishes to thank the following sponsors for their generous support of the 77th STLE Annual Meeting & Exhibition. Visit **www.stle.org/annualmeeting** for the most up-to-date list of additional sponsors and onsite signage in Long Beach. This list is complete as of April 25, 2023.*

Rhodium Level

($5,000)

Azelis L&MF US
Registration Bags

Ergon, Inc.
Badge Lanyards

Huntsman
Keynote Session

IMCD US
Annual Meeting Registration Confirmation

SI Group
Wi-Fi Service

The Lubrizol Corporation
Guest Room Keycards

Palladium Level

($4,000)

Afton Chemical Corporation
Refreshment Breaks & Water Stations

ANGUS Chemical
Directional Floor Signs

Daubert Chemical Company, Inc.
Networking Reception

Palmer Holland, Inc.
Annual Meeting Mobile App

Shell
Education Course Lunches

Soltex, Inc.
Refreshment Breaks & Water Stations

Titanium Plus Level

($3,000+)

BASF
Re-charging Lounge

Evonik Oil Additives USA, Inc.
Exhibitor Appreciation Hour Raffle

Ideas, Inc.
Welcome Gift

Titanium Level

($3,000)

Cargill
Education Course Materials

Infineum
Networking Reception

Teknor Apex
Networking Reception

The Timken Company
President's Luncheon

Vanderbilt Chemicals, LLC
Networking Reception

Platinum Level

($2,000)

King Industries, Inc.
Networking Reception

Sea-Land Chemical Company
Networking Reception

STLE Chicago Section
Networking Reception

Zschimmer & Schwarz
Speakers Breakfast

Gold Level

($1,000)

American Society of Mechanical Engineers (ASME)
Networking Reception

Bisley International, LLC
Networking Reception

Calumet Specialty Products Partners L.P.
Networking Reception

Compass Instruments
Networking Reception

Falex Corporation
Networking Reception

INEOS Oligomers
Networking Reception

SONGWON Management AG
Networking Reception

STLE Alberta Section
Networking Reception

STLE Detroit Section
Networking Reception

Tannas Company & King Refrigeration
Networking Reception

You work in a technical world.

You belong in a technical society.

You belong in STLE.

Keeping current with technical changes in the lubricants field is a daunting task.

More than 3,000 of your peers have solved this problem by joining the Society of Tribologists and Lubrication Engineers (STLE).

STLE is the premier technical organization representing tribology researchers and lubrication professionals.

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Learn more about the benefits of STLE membership and how to join at **www.stle.org.**

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Society of Tribologists and Lubrication Engineers
840 Busse Highway, Park Ridge, Illinois 60068 (USA)
P: (847) 825-5536 | F: (847) 825-1456 | www.stle.org | information@stle.org
Follow us on:

General information and policies

The exhibition is located in the Long Beach Convention Center – Hall B. (See map on page 9)

Exhibition Hours

- **Monday, May 22** (12:00 pm – 5:00 pm)

  Exhibitor Appreciation Hour (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win. (Booth #205)
- **Tuesday, May 23** (9:30 am – 12:00 pm) & (2:00 pm – 5:30 pm)
  Closed for President's Luncheon (12:00 pm – 2:00 pm)

  Exhibitor Appreciation Hour (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win. (Booth #205)
- **Wednesday, May 24** (9:30 am – 12:00 pm)

Registration Information

Annual Meeting registration entitles you to attend the technical sessions, trade show (Monday through Wednesday), Networking Reception on Monday evening, President's Luncheon on Tuesday afternoon and most other sanctioned annual meeting events.

President's Luncheon guest tickets are $50 – free to STLE Corporate Members **(two tickets)** and students – and can be purchased at the STLE registration desk in the Promenade Lobby of the Long Beach Convention Center.

Attendance at business meetings of technical committees and industry councils is open to anyone who is registered for the meeting. See condensed schedule (page 8) for time and location of individual technical committee and industry council meetings.

Registration Hours

Saturday, May 20 (12:00 pm – 6:00 pm)

Sunday, May 21 (6:30 am – 5:00 pm)

Monday, May 22 (6:30 am – 6:00 pm)

Tuesday, May 23 (6:30 am – 5:00 pm)

Wednesday, May 24 (6:30 am – 5:00 pm)

Thursday, May 25 (6:30 am – 12:00 pm)

Annual Meeting & Education Course Policies

- All attendees must be registered.
- All attendees receive a badge with their registration materials. The badge must be worn at all times and is required for admittance to any technical session, education course and the trade show.
- Badges may not be exchanged. Attendees who loan their badges to others will have their badges confiscated and their annual meeting privileges rescinded.
- Annual Meeting registration includes admittance to the trade show, technical sessions, Commercial Marketing Forum and all social events, including the Monday evening Networking Reception and Tuesday afternoon President's Luncheon.
- Distributing handouts at technical sessions is not permitted. Handouts will be given to education course attendees.
- Disseminating material or conducting business in the exhibit hall is not permitted if you are not an official exhibitor.

Recording Policy

Audio or video recording is not permitted in any of the annual meeting technical sessions or Commercial Marketing Forum presentations. Audio recording is permitted in the education courses with advance permission of the instructor. No video of any kind is permitted.

Photo Policy

STLE's official photographer will take photos of select technical sessions, Commercial Marketing Forum presentations, social events and the trade show on Monday and Tuesday. These photos will be used in print materials promoting the 2024 STLE Annual Meeting & Exhibition in Minneapolis, Minnesota (USA).

If you do not wish to have your photograph taken and published, please step out of the photo frame or notify the photographer afterwards if your photo has been taken so the image can be deleted.

stle
LONG BEACH
May 21-25, 2023

STLE Mobile App – Download Today!

Program updates will be posted daily in the Annual Meeting section of the STLE Mobile App (under the Events section). The STLE Mobile App is available for Apple and Android devices.

Apple iOS Android

Annual Meeting section sponsored by Palmer Holland.

Cellular Phone Policy

In order to not disturb speakers or fellow attendees, please keep cellular telephones on vibrate and leave the room to talk.

Dress Code

Business casual dress is appropriate for STLE events at the annual meeting. Technical session and education course speakers often choose attire that is more formal on the day of their presentations.

Harassment Policy

STLE is committed to providing an atmosphere that encourages the free expression and exchange of scientific ideas. As part of that commitment, STLE is dedicated to promoting a safe and welcoming environment for all participants attending the STLE Annual Meeting & Exhibition. All participants are expected to abide by this policy in all venues at the STLE Annual Meeting, including ancillary events and official and unofficial social gatherings. Harassment of any kind is strictly prohibited, and the Society will not tolerate acts in violation of this policy.

Any individual who believes that he or she has been the subject of, or has witnessed, harassment should immediately report the incident to STLE staff. All reports are confidential. A copy of the full policy is available at **www.stle.org**.

Statement on Diversity and Inclusion

STLE welcomes and encourages participation by all individuals regardless of age, culture, ethnicity, gender identity or expression, national origin, physical or mental difference, politics, race, religion, sex, sexual orientation, socio-economic status, or subculture. We strive to cultivate a society built on mentorship, encouragement, tolerance, and mutual respect, thereby engendering a welcoming environment for all.

Future Industry Meeting Dates

STLE Tribology Frontiers Conference
(co-located with STLE Tribology & Lubrication for E-Mobility Conference)
Cleveland Marriott Downtown at Key Tower
November 12-14, 2023
Cleveland, Ohio (USA)

STLE Tribology & Lubrication for E-Mobility Conference
(co-located with STLE Tribology Frontiers Conference)
Cleveland Marriott Downtown at Key Tower
November 14-15, 2023
Cleveland, Ohio (USA)

78th STLE Annual Meeting & Exhibition
Minneapolis Convention Center
May 19-23, 2024
Minneapolis, Minnesota (USA)

79th STLE Annual Meeting & Exhibition
Hyatt Regency Hotel
May 18-22, 2025
Atlanta, Georgia (USA)

80th STLE Annual Meeting & Exhibition
Hyatt Regency New Orleans
May 17-21, 2026
New Orleans, Louisiana (USA)

Get social with us!

Stay up to date on the latest annual meeting announcements and connect with fellow attendees using the conference hashtag **#STLE2023** on your favorite social media sites.

LinkedIn | **www.linkedin.com**
Twitter | **Twitter.com/STLE_Tribology**
Facebook | **Facebook.com/stle.org**
Instagram | **Instagram.com/STLE_Tribology**

2023 STLE Annual Meeting Special Events

All annual meeting events are in the Long Beach Convention Center.

New Member & Student Networking Reception

Sunday, May 21

6:00 pm – 8:00 pm | Bogart & Co.

This year's New Member and Student Networking Reception will be held at Bogart & Co., located in the Convention Center.

Come join other new STLE members and students for an evening of networking and great food, as well as build friendships and expand your professional connections. This event is for new members and students only!

Opening General Session

Monday, May 22

10:30 am – 12:00 pm | Grand Ballroom 1/2

STLE honors its esteemed journal publishing award recipients during the Monday General Session program. You'll also hear a keynote presentation from Angel Wileman, Manager, Thermofluids, with Southwest Research Institute, titled **"Hydrogen is Here: Are You Ready?"**

Tribology STEM Camp

Monday, May 22

9:30 am – 12:00 pm | Hall B

During STLE's 2023 Annual Meeting, the Society is hosting area high school students for its 7th Annual Tribology STEM Camp. Students will have the opportunity to see demonstrations and participate in hands-on experiments, led by engineers and scientists from the STLE community, to learn about areas of research within the fields of tribology and lubrication engineering. STLE's goal is to expose students interested in STEM (science, technology, engineering and mathematics) to careers in tribology and lubrication engineering.

Networking Reception

Monday, May 22

6:30 pm – 8:00 pm | Hyatt Hotel

This is the annual meeting's central networking event and a way for you to reconnect with old friends while making new ones. Since people come to STLE's Annual Meeting & Exhibition from around the world, this truly is an international event. Relax, socialize and add to your list of professional contacts through this outstanding networking event.

Exhibitor Appreciation Hour

Back by popular demand, two hours of dedicated exhibit time will occur at this year's show:

Monday, May 22 & Tuesday, May 23

3:00 pm – 4:00 pm | Hall B

Refreshments will be served in the trade show. Technical sessions, education courses, Commercial Marketing Forum presentations and all other annual meeting activities will cease at this time. Come support the meeting's exhibitors – and find solutions to your most pressing technical issues.

President's Luncheon & 77th STLE Annual Meeting Business Meeting

Tuesday, May 23

12:00 pm – 2:00 pm | Grand Ballroom

Ryan Evans

Hong Liang

Ticketed Event – The annual meeting's major business function draws virtually all attendees for a two-hour event honoring STLE's incoming and outgoing presidents, award winners and top volunteers. Come honor 2022-2023 President Ryan Evans with The Timken Company and 2023-2024 President Hong Liang with Texas A&M University.

Tickets to the luncheon are included with annual meeting registration and free to STLE Corporate Member representatives (two tickets) and students. Additional tickets may be purchased for $50 per person at the STLE Registration Desk in the Convention Center Foyer.

2023 STLE Annual Meeting

Opening general session

Hydrogen is Here: Are You Ready?

Monday, May 22

Keynote Address (10:30 am – 12:00 pm)
Long Beach Convention Center | **Grand Ballroom 1/2**

Keynote Speaker: Angel Wileman
Manager, Thermofluids, Souhwest Research Institute (SwRI)

Sponsored By HUNTSMAN
Enriching lives through innovation

Hydrogen has been "nearly" here for a long time but has never fully come to fruition due to the significant technical challenges with its production, storage, and use. However, hydrogen holds promise as a viable energy solution for global decarbonization. Hydrogen can be used as a tool to create electric power, heat our homes, and fuel our vehicles, without fear of contributing to climate change and its dangerous effect on human health and ecosystems. With the world's focused drive to become carbon neutral, industry has shifted back toward hydrogen as an energy solution. The time is now for making the leap from possibility to reality, but is society ready? Do we have sufficient solutions to the technical challenges that are introduced by using hydrogen as a global energy source?

The daunting list of technical challenges associated with global acceptance of hydrogen fuel starts with the high cost of production. Despite hydrogen being the most abundant element in the world, the current cost of hydrogen production is high,and significant work must be completed to make it an economically feasible option. Further, hydrogen has a small particle size and low density at ambient conditions, complicating material selection, component design, and storage options. Additionally, hydrogen is highly reactive and has a fast flame speed, which necessitates significant technological advancements prior to industry-wide use of hydrogen combustion engines.

In this keynote talk, we will investigate the wide variety of challenges facing hydrogen technology developers and give examples of research studies that are ongoing to address these challenges, making hydrogen a viable fuel that can play an important part in our sustainable future. The development of cost-effective and efficient hydrogen production technologies will be discussed, as well as the challenges associated with the storage, transportation, and use of hydrogen. The current U.S. and worldwide regulations around hydrogen will also be discussed, providing a peek into our hydrogen-fueled future.

Listen to the podcast: *Decarbonizing Hydrogen with Angel Wileman,* at: **www.swri.org/podcast/ep42** to learn more.

Angel Wileman *leads the Hydrogen Collaboration Initiative at Southwest Research Institute (SwRI), bringing together cross-functional teams to solve the world's toughest hydrogen technology challenges. Hailing from the University of Texas at Austin, where she obtained a master's degree in mechanical engineering, Angel has spent her career researching fluid effects on flow components and complex fluids processes for the energy industry. Having worked in several positions including academia and semiconductor manufacturing, Angel began her career at SwRI in 2011 and became manager of the Thermofluids Engineering Section in 2018. Angel was honored with the San Antonio Business Journal "40 under 40" Award in 2023 and the Empowering Women in Industry "Leadership in STEM" Award in 2019.*

2023 STLE Education Courses & Instructors

Please note all education courses are in the Long Beach Convention Center with the exception of Wednesday courses that are to be held in the Hyatt Regency Hotel.

The **2023 STLE Annual Meeting & Exhibition** features 11 industry-specific education courses offered on Sunday, May 21, Wednesday, May 24, and Thursday, May 25. The schedule is designed to give attendees more flexibility when planning their conference attendance. All courses are full day (start at 8:00 am and end by 5:00 pm). If you have not signed up for a course but would like to, please go to the STLE Registration Desk in the Promenade Lobby of the Long Beach Convention Center to check on availability. **Individuals will not be admitted to a course without registration.**

Sunday, May 21

Advanced Lubrication 301: Advanced Additives | 104B

Course Chair: Farrukh Qureshi, The Lubrizol Corporation

Advanced Lubrication 301 covers the molecular structures and chemistries of lubricant additive types. Additives examined will include antioxidants, rust inhibitors, detergents, dispersants, antiwear additives, extreme pressure additives, friction modifiers and rheology and viscosity modifiers.

Modules and Instructors:

- **Antioxidants & Rust Inhibitors,** Kevin DeSantis, BASF
- **Detergents & Dispersants,** Allison Williamson, The Lubrizol Corporation
- **Antiwear, Extreme Pressure & Friction Modifiers,** Eugene Scanlon, BASF
- **Rheology & Viscosity Modifiers,** Christopher Kabb, The Lubrizol Corporation

Who should attend: Engineers and scientists early/mid-career who want to brush up on their knowledge of lubricant additives.

Basic Lubrication 101 | 102C

Course Chair: Yvette Trzcinski, HF Sinclair

Basic Lubrication 101 is primarily for individuals entering the lubrication field who need a broad introduction to the field of lubrication, lubrication principles and lubricating materials. This course is also for individuals not directly involved but who need a broad overview of lubricants and basic lubricating components. This course does not require a formal scientific degree or background, although many technical terms and concepts are covered. Experienced industry professionals attend the course to be kept up to date on the latest developments, especially in those areas not directly related to their job function or area of expertise.

Modules and Instructors:

- **Lubrication Fundamentals,** Jake Finn, HF Sinclair
- **Base Oil Fundamentals,** Yvette Trzcinski, HF Sinclair
- **Additives,** Chris Schmid, The Lubrizol Corporation
- **Synthetics,** Tom Malinski, Chevron Phillips Chemical Company
- **Fundamentals of Grease,** David Turner, CITGO Petroleum Corporation
- **Lubricant Tests,** Raymond Drost, Calumet Specialty Products Partners, L.P.

Who should attend: Lubricant Sales Personnel, Additive Sales, Lubricant/Additive Marketing, Lubricant Formulator or Manufacturer, Academia, Base Stock Sales or Manufacturer, Original Equipment Manufacturer (OEM), Testing Equipment Manufacturer, Lubricant-Governing Associations.

Gears 101 | 102B

Course Chair: Larry Ludwig, Schaeffer Manufacturing Company

Gears 101 is designed to provide a general understanding of industrial gearing. This course will serve as a guide to establish not only a basic knowledge of gears and their supporting components but also their lubrication. In this course, you will learn about gear functions and types, basic gear terminology, the different types of industrial gear lubricants, the factors that affect gear lubrication, industrial gear lubricant requirements and their proper selection, open gear lubrication, gear wear modes, gear failure analysis and condition monitoring.

Modules and Instructors:

- **Gear Functions and Types**, Frank Uherek, Regal Rexnord
- **Gear Terminology,** Frank Uherek, Regal Rexnord
- **Gear Ratings,** Frank Uherek, Regal Rexnord
- **Gear Manufacturing,** Richard Butler, New Age Chemical
- **Gear Drive Components,** Frank Uherek, Regal Rexnord
- **Gear Failure Analysis – Modes, Effects and Patterns,** Frank Uherek, Regal Rexnord
- **Gear Failure Analysis – Root Cause Analysis,** Larry Ludwig, Schaeffer Manufacturing Company
- **Types of Industrial Gear Lubricants and Factors Affecting Their Lubrication,** Mike Holloway, 5th Order Industry
- **Industrial Gear Oil Requirements,** Mike Holloway, 5th Order Industry
- **Selection of Industrial Gear Lubricants,** Mike Holloway, 5th Order Industry
- **Gear Condition Monitoring,** Larry Ludwig, Schaeffer Manufacturing Company

Who should attend: Students, Lubricant Formulators, End-Users of Gear Lubricants, and anyone interested in knowing more about industrial gearing and their lubrication.

Hydraulics 201: Hydraulic Fluids and Systems Overview | 101A

Course Chair: Nathan Knotts, Chevron

This course provides an overview of the basic mechanical components used in hydraulic fluid power transmission. The composition and performance of hydraulic fluids will be discussed. The course will also feature sections on maintenance and troubleshooting as they pertain to hydraulic systems and in-service fluid analysis.

Modules and Instructors:

- **Hydraulic Fluids & System Overview,** Nathan Knotts, Chevron
- **Fluids Composition & Testing,** Nathan Knotts, Chevron

- **Fluid Degradation & Field Studies,** Scott Howard, Hy-Pro Filtration Corporation
- **Sustainability & Energy Efficiency,** Shubhamita Basu, The Lubrizol Corporation

Who should attend: Lubricant Sales Personnel, Additive Sales, Lubricant/Additive Marketing, Lubricant Formulator or Manufacturer, Academia, Base Stock Sales or Manufacturer, Original Equipment Manufacturer (OEM), Testing Equipment Manufacturer, Lubricant-Governing Associations.

Metalworking Fluids 130: Metal Treatment Chemical | 101B

Course Chair: Jennifer Lunn

While processing parts using metalworking fluids, there is a need for treating, cleaning, and protecting chemical and/or coatings. Substrates either are immersed in these chemicals or have them applied during some point of the processing. This course covers heat treating including oil and polymer quenching, cleaning parts and protecting parts from rust and corrosion. Individuals learn the basics of metallurgy as it applies to heat treating and quenching.

Modules and Instructors:

- **Metal Treating Fluids (Part I),** John Duggan, DuBois Chemicals, Inc.
- **Metal Treating Fluids (Part II),** John Duggan, DuBois Chemicals, Inc.
- **Metal Cleaning Fluid Chemistry,** Neil Canter, Chemical Solutions
- **Parts Cleaning Fundamentals – Importance of Cleaning and Rinsing,** Suresh Patel, BASF
- **Paint Pretreatments,** Suresh Patel, BASF
- **Metal Protecting (Part I),** Ben Faber, The Lubrizol Corporation
- **Metal Protecting (Part II),** Ben Faber, The Lubrizol Corporation
- **Metal Protecting Dry Films,** Richard Butler, New Age Chemical, Inc.

Who should attend: Chemists, Engineers, Technical Support Staff and Field Service Technicians working with and using metalworking fluids.

(NEW!)

Sustainability: Biolubricants and Biofuels | 104A

Course Chair: Brajendra K. Sharma, USDA

This course will be an overview of current progress in the development and use of biofuels and biolubricants. The course elements will include an introduction to energy and alternative fuels, basic chemistry of biofuels and biolubes, general performance requirements, overviews of market progress, niche markets, sustainability, and governmental and regulatory drivers. Products currently in various stages of commercialization will be discussed. Information on European, U.S. and OEM views will be included. The course will primarily focus on biolubricants but will include a general overview of alternative transportation fuels. Biofuel feedstocks, production and quality issues will also be covered. An outstanding list of speakers with first-hand knowledge in these areas will teach the course.

Modules and Instructors:

- **Introduction to Biofuels and Biolubricants,** Brajendra K. Sharma, USDA
- **Chemistry 101 – Petroleum and Biobased Lubricants,** Selim Erhan, Process Oils Inc.
- **Chemistry 101 – Petroleum and Biobased Fuels,** Dan Garbark, Battelle
- **Biofuel & Biolubricant Developments and Markets in the EU,** Stephan Baumgaertel, VSI – German Lubricant Manufacturers Association
- **Growth of "Niche" Markets in the US,** Larry Beaver, RSC Chemical Solutions
- **General Performance Requirements of Lubricants,** Mark Miller, Alliant Ventures
- **Biodegradation, Regulations and Standards,** Neil Canter, Chemical Solutions
- **USDA Biolubricant Programs,** Selim Erhan, Process Oils Inc.
- **Biofuels and Other Alternative Transportation Fuels,** Dan Garbark, Battelle
- **Biofuel Markets and OEM Concerns,** Alex Kulinowski, Afton Chemical Corporation
- **Sustainable Cooperation in the Lubricant Industry – A Transformation Towards a Circular and Sustainable Lubricant Value Chain,** Inga Herrmann, VSI – German Lubricant Manufacturers Association

Who should attend: Students, Engineers, Scientists, Lubricant Formulators, Users early/mid-career.

(NEW!)

Synthetics: Basics & Applications | 102A

Course Chair: Vasu Bala, Tiarco LLC

Designed primarily for formulators and users of lubricating materials, this course provides an overview of non-petroleum-based lubricants, their comparison to each other and to petroleum oil. It provides an introduction to synthetic lubricant basestocks and applications, as well as compares the use of these synthetic lubricants to petroleum-based products and between types of synthetic lubricants.

Modules and Instructors:

- **Introduction to Lubricant Classification,** Dennis Bachelder, American Petroleum Institute
- **Esters,** Gene Zehler, BASF
- **Polyglycols & Silicones,** Lauren Huffman, Dow Chemical Corporation
- **Polyalphaolefins,** Tom Malinski, Chevron Phillips Chemical Company
- **Alkylated Aromatics,** Najeeb Kuzhiyil, ExxonMobil Chemical
- **Phosphate Esters,** Salvatore Rea, LANXESS Solutions US
- **Food Processing Applications,** Tyler Housel, Zschimmer & Schwarz
- **Industrial Compressor Applications,** Glenn Short, BVA Inc.
- **Transportation Driveline Applications,** Donna Mosher, BASF
- **Gear Applications,** Larry Ludwig, Schaeffer Manufacturing Company
- **Wind Turbine Applications,** Philip Ma, BASF
- **Fire Resistant Fluids,** Salvatore Rea, LANXESS Solutions US
- **Synthetic Biolubricants,** Selim Erhan, Process Oils Inc.

Who should attend: Students, Engineers, Scientists, Lubricant Formulators, Users early/mid-career.

Wednesday, May 24

Advanced Lubrication 302: Advanced Lubrication Regimes | Regency DEFH (Hyatt Hotel)

Course Chair: Weixue Tian, ExxonMobil

Advanced Lubrication 302 goes more in-depth on lubrication regimes, wear, and wear mechanisms, as well as lubricant failure analysis. This course includes a series of lubricant failure analysis case studies on automotive engines, gears, and bearings.

Modules and Instructors:

- **Lubrication Regimes,** Brendan Miller, Chevron
- **Wear & Wear Mechanisms,** Ramoun Mourhatch, Chevron
- **Lubricant Failure,** Weixue Tian, ExxonMobil
- **Failure Analysis: Automotive Engines,** Hamed Ghaednia, Gehring L.P.
- **Failure Analysis: Gears,** Stephen Berkebile, US Army Research Laboratory
- **Failure Analysis: Bearings,** Daniel Merk, Schaeffler Technologies AG

Who should attend: Lubricant Sales Personnel, Additive Sales, Lubricant/Additive Marketing, Lubricant Formulator or Manufacturer, Academia, Base Stock Sales or Manufacturer, Original Equipment Manufacturer (OEM), Testing Equipment Manufacturer, Lubricant-Governing Associations.

Basic Lubrication 102 | Regency A (Hyatt Hotel)

Course Chair: Yvette Trzcinski, HF Sinclair

Basic Lubrication 102 is an overview of equipment systems (gears, bearings, seals, compressors, and engines) and their lubrication requirements, including a module on grease. Like Basic Lubrication 101, this course does not require a formal scientific degree or background, although many technical terms and concepts related to the use of lubricants in various mechanical devices are covered. This course is intended for a diverse group, including individuals involved in technical service, sales, marketing, manufacturing, maintenance, and managers who want to know more about how lubricants work in service. This course assumes fundamental knowledge of lubricants and lubrication principles, as presented in the Basic Lubrication 101 course.

Modules and Instructors:

- **Gear Fundamentals,** Frank Uherek, Regal Rexnord
- **Fundamentals of Hydraulics,** Nathan Knotts, Chevron
- **Seals,** Gareth Fish, The Lubrizol Corporation
- **Compressors,** Joe Schultz, The Lubrizol Corporation
- **Bearings & Lubrication Systems,** Paul Shiller, First Power Group
- **Gasoline & Diesel Engines,** Jake Finn, HF Sinclair

Who should attend: Lubricant Sales Personnel, Additive Sales, Lubricant/Additive Marketing, Lubricant Formulator or Manufacturer, Academia, Base Stock Sales or Manufacturer, Original Equipment Manufacturer (OEM), Testing Equipment Manufacturer, Lubricant-Governing Associations.

Metalworking Fluids 250: Understanding and Controlling Metal Removal | Regency BC (Hyatt Hotel)

Course Chair: Kevin Saunderson, BP

Once a metalworking fluid has been qualified for use in an application, its performance depends on successful fluid management. In turn, successful fluids management depends on a fundamental understanding of the factors that work against fluid life and fluid performance, as well as cost-effective strategies for preventing these factors from causing metal - working fluid failure. Metalworking Fluids 250 is designed to meet both of these needs. It covers primary failure mechanisms, including the effect of contaminant particle size, water quality, microbes and oil contamination. Also presented are recommendations on how best to prevent each of these factors from destroying metalworking fluid performance and shortening metalworking fluid functional life.

Modules and Instructors:

- **Metal Worked and Particle Size Considerations,** John Burke, Consultant
- **Filtration,** Craig Thomas, J.R. Schneider Company
- **Water Quality,** Bridget Dubbert, Engineered Lubricants Company
- **Extraneous Oils, Contamination Effects & Control Practices,** John Burke, Consultant
- **Microbial Concerns & Controls,** Fred Passman, BCA, Inc.
- **Foam Issues & Concerns,** Michael Staples, Kao Chemicals GmbH
- **Corrosion Causes, Concerns & Controls,** Neil Canter, Chemical Solutions
- **Compatibility Concerns,** Bill Downs, DuBois Chemicals, Inc.
- **Root Cause Analysis,** Fred Passman, BCA, Inc.

Who should attend: Plant Managers, Shop Supervisors, Chemical Management Personnel, Technical Sales and Marketing Personnel, Health & Safety or Environmental Affairs Personnel, Maintenance Personnel, Waste Treatment Personnel, Coolant Compounder – Technical Service and Laboratory Personnel, Chemical Process Operators, Individuals new to metalworking technology.

Thursday, May 25

Electric Vehicles | 104A-B

Course Chair: Carlos Sanchez, Southwest Research Institute

This course introduces hardware, tribology, lubrication, thermal management, and testing related to EV. It includes an overview of hybrid, fully battery and fuel-cell electric vehicles and covers the driveline systems of hybrid and full electric units. Other topics covered include lubricant, tribology and thermal management challenges and requirements for EVs and concludes with discussion about established test methods for EV fluid evaluation.

Modules and Instructors:

- **An Overview of Hybrid Full Electric and Fuel Cell Vehicles,** Peter Lee, Southwest Research Institute
- **Hardware Design and Drive Unit,** Peter Lee, Southwest Research Institute
- **Lubricant Requirements for Electric Vehicles,** Chris Cleveland & Lisa Thalen, Afton Chemical Corporation
- **Lubricating Greases for Electric Vehicle Applications,** Gareth Fish, The Lubrizol Corporation
- **Heat Transfer and Thermal Management in HEV and EV,** Thomas Wellmann, FEV North America
- **Test Methods for Evaluation of Electric Vehicle Fluids,** Rebecca Warden, Chevron Oronite
- **eTribology: Experimental Methods for Evaluating EV Fluids and Materials,** Harpal Singh, Consultant

Who should attend: Lubricant Manufacturers, Raw Material Suppliers, Distributors, End-users of Lubricants, Senior Corporate Management, Technical Sales and Marketing Personnel Formulators, Engineers & Chemists, Plant Managers, Research & Product Developers.

Award recipients

STLE would like to congratulate the following individuals who will be recognized for their outstanding technical achievements in the field of tribology and lubrication during the 2023 STLE Annual Meeting & Exhibition, in Long Beach, California.

Publishing awards are given in recognition of outstanding achievement in the field of tribology and lubrication. All awards are for papers printed in **Tribology Transactions,** STLE's peer-reviewed journal.

Edmond E. Bisson Award

The Bisson Award was named in honor of Edmond E. Bisson, a former STLE editor-in-chief who was instrumental in establishing the society's reputation as a technical publisher. Established in 1991, the award is given to STLE members or non-members for the best written contribution published by the society in the year preceding the Annual Meeting. The contribution must deal with tribology, lubrication engineering or allied disciplines.

- **Arman Mohammad Khan,** Northwestern University (USA)
- **Q. Jane Wang,** FSTLE, Northwestern University (USA)
- **Juan Esteban Fernandez,** Azul 3D, Inc. (USA)
- **Zhe Li,** General Motors Corporation (USA)
- **Yuchuan Liu,** General Motors Corporation (USA)

"Friction at Ring-Liner Interface Analyzed with a Systematic Surface Characterization"

Frank P. Bussick Award

The Bussick Award is presented for the most outstanding technical paper written on sealing systems technology and materials. The award is sponsored by the STLE Seals Technical Committee and honors a former committee chair and STLE board member.

- **Abdolkarim Sheikhansari,** The University of Sheffield (United Kingdom)
- **Jonathan Knapton,** Dawn Aerospace (United Kingdom)
- **Diego Benito,** Rolls-Royce plc (United Kingdom)
- **Ben Shaw,** Rolls-Royce plc (United Kingdom)
- **Ehsan Alborzi,** The University of Sheffield (United Kingdom)
- **Simon Blakey,** University of Birmingham (United Kingdom)

"Development of an Apparatus for Testing of High-Temperature Static Seals"

Walter D. Hodson Award

The Hodson Award was established in 1950 and is given to the lead author of the best paper written by an STLE member 35 years of age or younger and published by the society in the year preceding the Annual Meeting. The purpose of the award is to stimulate the interest of young engineers in the science of tribology and lubrication and the activities of STLE.

- **Rami Kerrouche** (*lead author), National Research Council (Canada)
- **Azzedine Dadouche,** National Research Council (Canada)
- **Mahmoud Mamou,** National Research Council (Canada)
- **Salah Boukraa,** University of Blida (Algeria)

"Power Loss Estimation and Thermal Analysis of an Aero-Engine Cylindrical Roller Bearing"

Wilbur Deutsch Memorial Award

The Deutsch Award is named for a former STLE president and recognizes the most outstanding technical paper written on the practical aspects of lubrication published by the society in the year preceding the Annual Meeting.

- **Robert Jan Meijer,** University of Twente (The Netherlands)
- **Piet M. Lugt,** University of Twente/ SKF Engineering & Research Centre B.V. (The Netherlands)

"The Grease Worker and its Applicability to Study Mechanical Aging of Lubricating Greases for Rolling Bearings"

Captain Alfred E. Hunt Award

Named for ALCOA's first president, this award is given annually to the STLE member or members authoring the best technical paper dealing with the field of lubrication or an allied field.

- **Thomas Russell,** Purdue University (USA)
- **Farshid Sadeghi,** FSTLE, Purdue University (USA)
- **Wyatt Peterson,** Purdue University (USA)
- **Saeed Aamer,** Purdue University (USA)
- **Ujjawal Arya,** Purdue University (USA)

"A Novel Test Rig for the Investigation of Ball Bearing Cage Friction"

Al Sonntag Award

The Sonntag Award was established in 1983 and is given to an STLE member or members authoring the best technical paper on solid lubricants published by the society in the year preceding the Annual Meeting.

- **Sujan K. Ghosh,** University of Arkansas at Little Rock (USA)
- **Nathaniel Harris,** University of Arkansas (USA)
- **Neda Mahmoudi,** SurfTec, LLC (USA)
- **Dipankar Choudhury,** Dexcom (USA)
- **Josue A. Goss,** University of Arkansas (USA)
- **Samuel Beckford,** SurfTec, LLC (USA)
- **Min Zou,** FSTLE, University of Arkansas (USA)

"Improving the Tribological Performances of PDA + PTFE Nanocomposite Coatings by Hot Compaction"

(continued on page 24)

How long will your **fluid last?**

Extend the life of your metalworking fluids with Synergex™ multifunctional amine additives. This range of lower-odor, lower-volatility products from Eastman offers excellent buffering and pH stability.

Learn more at ***eastman.com/synergex***.

Visit us at STLE booth 610.

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Industry Service Awards Recipients

STLE International Award

Dr. Ewa Bardasz, FSTLE, ZUAL Associates in Lubrication (USA)

The International Award, which was established in 1948, is STLE's highest technical honor and bestows lifetime honorary membership on the recipient, who need not have been a member of STLE. It is given in recognition of the recipient's outstanding contributions in tribology, lubrication engineering or allied fields.

P.M. Ku Meritorious Award

Greg Croce, CLS, Chevron Products Company (USA)

Paul Hetherington, CLS, HF Sinclair (retired) (USA)

The Ku Award was established in 1978 and is given to the STLE member who most typifies the dedicated spirit of the late P.M. Ku, who worked tirelessly to promote and advance the mission of STLE. The award has been established to recognize outstanding and selfless achievement on behalf of STLE. To qualify for the honor, the recipient must have been a member of the society for at least 15 consecutive years and performed extensive active, dedicated service.

Vic Joll Award

Dr. William Tuszynski, The Unami Group, STLE Philadelphia Section (USA)

The Vic Joll Award recognizes outstanding and selfless contributions by a member of an STLE local section. It is given to a section member who has worked tirelessly and continuously for the benefit of the section, devoting numerous hours in the performance of many tasks necessary to promote and advance the mission of the section and of STLE. The award is named in honor of the late Vic Joll, 1978-79 STLE president who championed local sections.

Raymond L. Thibault Excellence in Education Award

Ruediger Krethe, CLS, OilDoc GmbH (Germany)

The Raymond L. Thibault Excellence in Education Award was established in 2020 and is given to an STLE member who has demonstrated dedication to passionate and influential work as an educator in practical aspects of tribology and lubrication engineering which benefits the STLE community.

2023 STLE Fellows

STLE Fellows are persons of outstanding personal achievement in the field of tribology or lubrication engineering who have 20 years of active practice in the science and/or engineering professions and have been an STLE member for 10 years. Individuals are nominated by the Fellows Committee and approved by the STLE board of directors.

Dr. Hong Gao, FSTLE, Shell Global Solutions (US) Inc. (USA)

Dr. Ken Hope, FSTLE, CLS, Chevron Phillips Chemical Company (USA)

Dr. Peter Lee, FSTLE, Southwest Research Institute (USA)

Dr. Shuangbiao (Jordan) Liu, FSTLE, Northwestern University (USA)

Dr. Steve Shaffer, FSTLE, Shaffer Tribology Consulting (USA)

Outstanding STLE Local Section Awards

- **STLE Houston Section**
- **STLE Philadelphia Section**

Student Scholarships

Presidential Awards Program

STLE grants three academic awards through its Presidential Awards Program: The Elmer E. Klaus Fellowship (graduate students), The E. Richard Booser Scholarship (undergraduate students) and The Jeanie S. Scholarship (female undergraduate or graduate students). These awards are administered by the STLE Presidential Council and are meant to encourage students to pursue an advanced degree or a career in tribology or lubrication engineering by subsidizing a research project related to the field.

The Elmer E. Klaus Fellowship: Seokhoon Jang, Penn State University (USA)

Nicolas Molina Vergara, The University of Texas at Austin (USA)

The E. Richard Booser Scholarship: Jackson Swets, Gonzaga University (USA)

The Jeanie S. McCoy Scholarship: Allison Chau, University of California, Santa Barbara (USA)

Early Career Awards

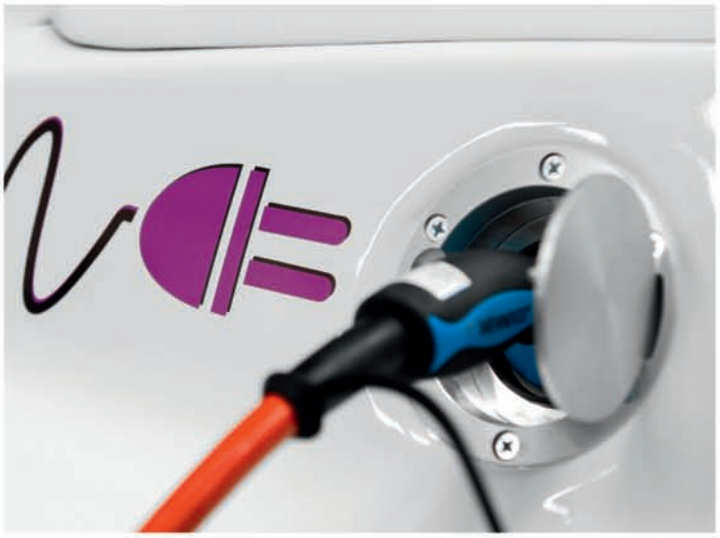
This award recognizes the technical achievements of STLE student members, postdoctoral researchers, junior-level academic faculty & industry professionals and provides financial support for attendance to the STLE Annual Meeting.

Student Allison Chau, University of California, Santa Barbara (USA)

Postdoctoral Researcher Dr. Pranjal Nautiyal, University of Pennsylvania (USA)

Academic Professional Dr. Prathima Nalam, University at Buffalo (USA)

Industry Professional Dr. Mao Ueda, Shell Lubricants Japan (Japan)



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VISIT US AT THE STLE ANNUAL MEETING & EXHIBITION

BOOTH #111

May 21-25, 2023

Long Beach Convention Center, Long Beach, CA.

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Overview

Download the STLE Mobile App for the most up-to-date schedule. (pg. 15)

Sunday, May 21

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Education Course Speakers Breakfast
7:00 am – 7:45 am – **Grand Ballroom**

Education Courses* (8:00 am – 5:00 pm)

- Advanced Lubrication 301: Advanced Additives – **104B**
- Basic Lubrication 101 – **102C**
- Gears 101 – **102B**
- Hydraulics 201: Hydraulic Fluids and Systems Overview – **101A**
- Metalworking Fluids 130: Metal Treatment Chemical – **101B**
- Sustainability: Biolubricants and Biofuels **(New!)** – **104A**
- Synthetics: Basics & Applications **(New!)** – **102A**

Refreshment Break
10:00 am – 10:30 am – **Foyer**

STLE New Member & Student Networking Reception
6:30 pm – 8:00 pm – **Bogarts & Co.**

Monday, May 22

Registration
6:30 am – 6:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Technical Sessions (8:00 am – 10:00 am)

- 1A • Lubrication Fundamentals I: Forecasting Trends – **101A**
- 1B • Rolling Element Bearings I – **101B**
- 1C • Sustainable Power Generation I – **102A**
- 1D • Materials Tribology I – **102B**
- 1E • Condition Monitoring I – **102C**
- 1G • Nonferrous Metals I – **103B**
- 1H • Commercial Marketing Forum I – **103C**
- 1I • Electric Vehicles I – **104A**
- 1K • Metalworking Fluids I – **201A**
- 1M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling I – **202A**
- 1N • Nanotribology I – **202B**
- 1O • AI and Machine Learning I – **202C**

Refreshment Break
10:00 am – 10:30 am – **Grand Ballroom Foyer**

Opening General Session (10:30 am – 12:00 pm)
Keynote Address – **Grand Ballroom 1/2**

- **"Hydrogen is Here: Are You Ready?"**
  Speaker: Angel Wileman, Manager, Thermofluids, Southwest Research Institute (SwRI)

Lunch (on your own) – 12:00 pm – 1:30 pm

Commercial Exhibits and Student Posters
12:00 pm – 5:00 pm – **Hall B**

Technical Sessions (1:30 pm – 6:00 pm)

- 2A • Lubrication Fundamentals II: Marine Engines – **101A**
- 2B • Rolling Element Bearings II – **101B**
- 2C • Wind Turbine Tribology I – **102A**
- 2D • Materials Tribology II – **102B**
- 2E • Condition Monitoring II – **102C**
- 2F • Environmentally Friendly Fluids I – **103A**
- 2G • Nonferrous Metals II – **103B**
- 2H • Commercial Marketing Forum II – **103C**
- 2I • Electric Vehicles II – **104A**
- 2K • Metalworking Fluids II – **201A**
- 2M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling II – **202A**
- 2N • Nanotribology II – **202B**
- 2O • AI and Machine Learning II – **202C**

Exhibitor Appreciation Break
3:00 pm – 4:00 pm – **Hall B**

Networking Reception
6:30 pm – 8:00 pm – **Hyatt Hotel**

Exhibition hours

- **Monday, May 22** (12:00 pm – 5:00 pm)
- **Exhibitor Appreciation Hour** (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win.
  (Booth #205)

TIME	SESSION 1A Lubrication Fundamentals I: Trends Room 101A	SESSION 1B Rolling Element Bearings I Room 101B	SESSION 1C Sustainable Power Generation I Room 102A
8:00 am – 8:30 am	What Makes a Sulfur Compound Inactive versus Active? An Examination of Sulfur Compounds and its Effect on Lubrication, J. Williams, p. 32	Experimental Validation and Comparison of Friction Torque Models for Rolling Element Bearings, J. Kelley, p. 32	
8:30 am – 9:00 am	Sustainable Cooperation in the Lubricant Industry – A Transformation Towards a Circular and Sustainable Lubricant Value Chain!, I. Herrmann, p. 32	Cryogenic Test and Evaluation of Pin-on-Disk with the Various Cage Materials for Solid Lubricated Bearings, W. Kwak, p. 32	Towards an Accelerated Protocol for the Evaluation of Solar Cells, E. Georgiou, p. 33
9:00 am – 9:30 am	Challenges for Lubrication R&D in Future Powertrains Applications and Potential Solutions in Precompetitive Research, C. Kunze, p. 32	Augmented Lubricant Replenishment for Rolling Bearings at Limited Lubricant Supply Conditions, P. Wong, p. 33	Advances in Varnish Condition Monitoring, E. Hepley, p. 33
9:30 am –10:00 am		An Improved Dynamic Bearing Model Considering Cage Lubrication, T. Russell, p. 33	Sustainable Aeroderivative Gas Turbine Operation Through Lubricant Chemistry Management, M. Hobbs, p.33
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2A **Lubrication Fundamentals II: Marine Engines** **Room 101A**	**SESSION 2B** **Rolling Element Bearings II** **Room 101B**	**SESSION 2C** **Wind Turbine Tribology I** **Room 102A**
1:30 pm – 2:00 pm	Performance of Additives Improving Asphaltene Dispersancy in GII Base Stocks, A. Jha, p. 43	Contribution of Rolling Bearings to Improve Driving Range of Electric Vehicles, J. Modi, p. 44	
2:00 pm – 2:30 pm	Experimental Evaluation on a Special Cylinder Oil Additive Package Applied in Blender on Shipboard, J. Zhang, p. 43	Influence of Bearing and System Design on CO_2 Emission Savings, V. Bakolas, p. 44	Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment Continued, M. Blumenfeld, p. 46
2:30 pm – 3:00 pm	Varnish Resistance Prediction Indicator (VRPI) for Group I-IV Lubricants, J. Fotue, p. 43	Influence of Form Deviated Bearing Seats on the Operating Behavior of Cylindrical Roller Bearings O. Koch, p. 44	Autonomously Triggered Application of Corrosion Preventing Lubricants, S. Flank, p. 47
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Study of Tribological Contact Condition Using the Non-linear Behavior of Longitudinal Ultrasonic Waves, S. Taghizadeh, p. 43	Experimental and Analytical Investigation of Oil Flow in a Ball Bearing, U. Arya, p. 46	Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound, G. Nicholas, p. 47
4:30 pm – 5:00 pm	Reduction of Carbon Footprint and Maintenance of Oil Life through Performance Selection of Lube Oils, G. Natrajan, p. 44	Experimental and Analytical Investigation of Angular Contact Ball Bearing Cage Pocket Lubrication, S. Aamer, p. 46	Sustainable Solutions for Wind Turbines, M. Combarros, p. 47
5:00 pm – 5:30 pm	Accelerating the Development of Piston-Liner Tribology in Marine Diesel Engines Using Ultrasonic Transducers, O. Spenceley, p. 44	In Situ Measurement of Grease Churn within a Full-Scale Cylindrical Roller Bearing, W. Gray, p. 46	Using a Rheometer to Test the Performance of Greases in an Oscillating Ball Bearing, M. Bartram, p. 47
5:30 pm – 6:00 pm		Long-Term Investigations of Different Bearing Configurations at Solid-Lubricated Rolling Bearings, M. Werner, p. 46	Sustainable Power Generation & Wind Turbine Tribology Business Meeting
6:00 pm – 6:30 pm			

SESSION 1D Materials Tribology I Room 102B	SESSION 1E Condition Monitoring I Room 102C		
Orientation Controls Tribological Performance of 3D-Printed Model Thermoplastics, S. Arfin Mahmood, p. 34	A Hybrid Modeling Approach for Transferring Machine Learning Assisted Condition Monitoring of Rolling Bearings to Differing Machine Types, C. Bienefeld, p. 34		8:00 am – 8:30 am
A Ready-to-Use Temperature Model for Polymer/ Steel Contacts, M. Kalin, p. 34	Application of Envelope Spectrum Analysis and Spectral Kurtosis to Diagnose Debris Fault in Bearing using Acoustic Signals, H. Omoregbee, p. 35		8:30 am – 9:00 am
Characterizing Billiard Chalk in the Cue Tip-Cue Ball Interface, A. Martin, p. 34	Anomaly Detection Methodology for Centrifugal Compressors and Steam Turbines, M. Khandelwal, p. 35		9:00 am – 9:30 am
Nanoscale Rate-and-State Friction, Atomic Insights Via Complex Sliding Protocols, J. McClimon, p. 34	The Opportunities of Rolling Bearing Impedance Signal Analysis for Condition Monitoring, F. Michael Becker-Dombrowsky, p. 35		9:30 am –10:00 am
Break	**Break**	**Break**	10:00 am – 10:30 am

SESSION 2D Materials Tribology II Room 102B	SESSION 2E Condition Monitoring II Room 102C	SESSION 2F Environmentally Friendly Fluids I Room 103A	
Effect of Diamond-Like Carbon Composition on Oxidation Reactivity and Friction, S. Jang, p. 47	Lifetime Extension Strategies in Wind Turbine Using an OCM – Oil Condition Monitoring Program, Y. Gomez, p. 50	Global Fluid Trends, E. Jones, p. 52	1:30 pm – 2:00 pm
Process-Structure-Property Driven Development of High-Quality MoS_2 Coatings, T. Babuska, p. 48	Suggested Sampling Methods for In-Service Oil and Grease Lubricated Equipment, V. Bunchek, p. 50	Using the Life Cycle Assessment (LCA) Tool to Determine the Carbon Footprints of Castor Oil Derivatives, T. Thompson, p. 52	2:00 pm – 2:30 pm
Quality Assurance Methods for MoS_2-Based Solid Lubricants, M. Dugger, p. 48	Optimizing Operational Savings with Fluid Analysis, H. Neicamp, p. 50	Potential of Lubricant Base Oils from Microalgae, B. Sharma, p. 52	2:30 pm – 3:00 pm
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	3:00 pm – 4:00 pm
Wear and Corrosion Resistant Ni-SiC Coatings Fabricated by Adaptive Additive Manufacturing, M. Tajedini, p. 48	A Sea Change in Fluid Analysis (a.k.a. Oil Analysis) Has Arrived, J. Poley, p. 50	Maximize Performance and Improve Sustainability Through Use of Group V Ester Technology, G. Stephenson, p. 52	4:00 pm – 4:30 pm
High-Frequency Reciprocating Tribological Assessment of MoVN-Cu Coating in Low-Viscosity Fuel Environments under Various Load, Temperature, and Sliding Velocity Conditions, K. Jacques, p. 48	Using Oil Analysis to Identify Incorrect Bearing Lubrication, E. Zabawski, p. 50	Overcoming the High Viscosity Limitation of Readily Biodegradable EAL Base Fluid, R. Navaratnam, p. 52	4:30 pm – 5:00 pm
Ultralow Wear PEALD Ternary Nitrides: Understanding Process-Structure-Property Relationships, K. Van Meter, p. 48	Using Oil Analysis to Determine Root Cause of an Overheated Gearbox, E. Zabawski, p. 50		5:00 pm – 5:30 pm
	Condition Monitoring Business Meeting		5:30 pm – 6:00 pm
			6:00 pm – 6:30 pm

MONDAY >>

TIME	SESSION 1G Nonferrous Metals I Room 103B	SESSION 1H Commercial Marketing Forum I Room 103C	SESSION 1I Electric Vehicles I Room 104A
8:00 am – 8:30 am	Emulsions for Aluminum Hot Rolling: Which Droplet Size Distribution is Beneficial to Lubricity?, A. Viat, p. 35	Chevron Phillips – PAOs in Thermal Management Applications, K. Hope, p. 36	
8:30 am – 9:00 am	Additives for High Lubricity Fully Synthetic Aluminum Machining Formulations, T. Meyers, p. 35	Huntsman – Amines for Fuel and Lube Applications, H. Zhao, p. 36	Electrical Behaviors of Tribocontacts in Association with Friction and Wear Properties as Key Concepts for Lubes in Electrified Powertrains, M. Woydt, p. 36
9:00 am – 9:30 am	Correlations Between Two Methods for Cloud Point and Pour Point Determination of Biobased Materials, G. Bantchev, p. 35	ANGUS Chemical Company – Addressing the Emerging Environmental and Performance Challenges of Tomorrow with ANGUS' Multifunctional Additives, M. Chen, p. 36	Can Conventional ATFs be Used Safely in Electrified Transmissions?, A. García Tuero, p. 38
9:30 am –10:00 am	Hot Mill Coolant Filtration Improvements, A. Knopp, p. 36	Colonial Chemical: ColaCor 186: A Unique Core Carboxylic Acid for Corrosion Inhibitors, S. Tang, p. 36	Development of Test Methods and Fluid Durability Study in Electrified Drivetrains, C. Hudson, p. 38
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2G **Nonferrous Metals II** **Room 103B**	**SESSION 2H** **Commercial Marketing Forum II** **Room 103C**	**SESSION 2I** **Electric Vehicles II** **Room 104A**
1:30 pm – 2:00 pm	Improving Aluminum Cold Mill Lubricant Performance with a Surface Active Agent, T. Oleksiak, p. 54	Evonik Oil Additives: Novel Base Oil Technologies for Automotive Driveline Fluids, J. Langston, p. 54	Various Copper Corrosion Test Methods for Electric Drivetrain Fluid Evaluations, Y. Kwak, p. 56
2:00 pm – 2:30 pm	Carbon Negative Liquid Hydrocarbons: Next Generation GTL Technology Commercializing in the US, W. Anderson, p. 54	LANXESS – Advances in H1 Food Grade Calcium Sulfonate Greases: A Continued Vision 20 Years On, R. Dworet, p. 54	Next-Generation Tribology Component Technologies for E-Fluids, C. Chretien, p. 57
2:30 pm – 3:00 pm	Considerations for Changing Cold Rolling Base Oil, J. Anglin, p. 54	The Lubrizol Corporation – Redefining Long Drain Hydraulic Fluids, S. Basu, p. 56	Technologies for Improving the Performance of E-axle Fluids, M. Iino, p. 57
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Influence of Raw Material Quality Variations on the In-service Performance of Aluminum Hot Rolling Oils, J. Leimhofer, p. 54	ExxonMobil – EHC 340 MAX™: Elevating Extra Heavy Base Stocks, B. Duggal, p. 56	Performance Characteristics of Some EV Drivetrain Lubricants Under Electrified Condition, A. Erdemir, p. 57
4:30 pm – 5:00 pm	Nonferrous Metals Business Meeting	IMCD – A Sustainablexxx Solution for an Evolving World – Esters as Base Oils and Components to Design a More Innovative Future, V. Aruta, p. 56	Comparison of Electric Drive Unit Lubricant Aeration Under High Speed Operation, C. Frazier, p. 57
5:00 pm – 5:30 pm		OQ Chemicals – Synergistic Effects of a Blend of Polyalphaolefin and Polyol Ester for Potential High-Performance Lubricants in Electric Vehicles, K. Gross, p. 56	Electrically Conductive Nanoparticle Additives for Greases Used in Electric Vehicles and Other Applications, R. Jackson, p. 57
5:30 pm – 6:00 pm		Richful Lube Additive Company Development Progress by 2022, Y. Tao, p. 56	Sustainable E-Fluid Concepts for Electric Motor Cooling and Gearbox Lubrication, C. Dobrowolski p. 57
6:00 pm – 6:30 pm			

SESSION 1K
Metalworking Fluids I

Room 201A

	Improving Metalworking Fluid Efficiency by Creating Hydrophilic Protective Barriers, V. Demel, p. 38		8:00 am – 8:30 am
	Overcoming Metalworking Fluid Instability: Beyond HLB, H. Kim, p. 38		8:30 am – 9:00 am
	A Novel Way to Measure Stability and Shelf-Life of a Metalworking Fluid Formulation, R. Elupula, p. 38		9:00 am – 9:30 am
	Surfactant Roles in Emulsifiable Oils, R. Golden, p. 40		9:30 am –10:00 am
Break	Break	Break	10:00 am – 10:30 am

SESSION 2K
Metalworking Fluids II

Room 201A

	ASTM Standards Addressing Metalworking Fluid Health and Safety Issues, F. Passman, p. 58		1:30 pm – 2:00 pm
	The Study of Novel Calcium Overbased Sulfonates Used for Rust Preventives, J. Jianjun Wei, p. 58		2:00 pm – 2:30 pm
	Case Study of Monitor and Correction of Field Coolant Emulsions by Light Scattering Instrument and Good Correction Method, Y. Philip Zhao, p. 58		2:30 pm – 3:00 pm
Exhibitor Appreciation Break	Exhibitor Appreciation Break	Exhibitor Appreciation Break	3:00 pm – 4:00 pm
	Extreme Pressure Sulfurized Additives for Metalworking Fluid Ester-Based Formulation, G. Notheaux, p. 58		4:00 pm – 4:30 pm
	Sustainability Beyond Carbon Footprint, M. Stapels, p. 58		4:30 pm – 5:00 pm
	Chlorine Use in Stainless Steel Tube Manufacturing, J. Brooks, p. 58		5:00 pm – 5:30 pm
	Analysis of the Tool Margin-Wall Contact During MQL Deep-Hole Drilling of AISI 4140 Steel Through a Surface Integrity Study, P. Neal, p. 58		5:30 pm – 6:00 pm
			6:00 pm – 6:30 pm

MONDAY >>

TIME	SESSION 1M Lubrication and Tribology Modeling I Room 202A	SESSION 1N Nanotribology I Room 202B	SESSION 1O AI and Machine Learning I Room 202C
8:00 am – 8:30 am		Nano-scale Friction of Graphitic Surfaces in n-hexadecane, B. Baboukani, p. 42	Deep Learning Data-Driven Model for Coefficient of Friction Prediction of Lubricated Tribo-pairs, M. Oramas, p. 42
8:30 am – 9:00 am	Homogenization, HMM and Patir & Cheng: The Method that Changed the Game, A. Almqvist, p. 40	AFM Cantilever Tip Radius Estimation Through Contact Resonance Force Spectroscopy, T. Mathias, p. 42	
9:00 am – 9:30 am	A Mixed Lubrication Model of Piston-on-Ring Contacts Considering Temperature Dependent Shear Thinning and Elastic-Plastic Contact, R. Jackson, p. 40	The Effects of -H and -OH Termination on Adhesion, Friction, and Wear of Silicon-Silicon Interfaces: A Molecular Dynamics Investigation, J. Harrison, p. 42	Towards the Prediction of EHL Film Thickness Parameters by Machine Learning Approaches, M. Marian, p. 43
9:30 am –10:00 am	From Photosynthetic Carbon Capture to Self-Healing Tribofilms, Y. Jeng, pg. 40	Unique Frictional Characteristics of Germanium-based Nanofilm, C. Xu, p. 42	Digitalization: Bringing a "Frictionless" Future Closer to Reality, S. Gullapalli, p. 43
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2M **Lubrication and Tribology Modeling II** **Room 202A**	**SESSION 2N** **Nanotribology II** **Room 202B**	**SESSION 2O** **AI and Machine Learning II** **Room 202C**
1:30 pm – 2:00 pm	Frontiers of Surface Engineering and ribology for a Green and Sustainable Future, A. Erdemir, p. 60	Invited Talk – The Nucleation, Growth, and Adhesion of Water Bridges in Sliding Nano-Contacts, B. Weber, p. 62	A New Perspective on Tribological Data via Advanced Statistics and Artificial Intelligence, N. Dörr, p. 64
2:00 pm – 2:30 pm	Fluid/Solid Interactions in Lubrication – Recent Developments and Future Perspectives, D. Dini, p. 60		Chemometric and FTIR Spectroscopy for Determination of Physicochemical Properties of Engine Oil, G. Natrajan, p. 64
2:30 pm – 3:00 pm	Unsteady Multiscale Simulation of Lubricated Rough Surfaces, N. Brunetiere, p. 60	Molecular Dynamics Investigation of the Friction Mechanism in a Humid Nanocontact, I. Stankovic, p. 62	Digital Advancements in Tribofilm Analysis, O. Ogunsola, p. 64
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Explicit Flow-Continuity-Enforced Elastohydrodynamic Lubrication Analyses with a Mass Conservation Algorithm, S. Liu, p. 60	Using Friction Hysteresis of 2D Materials to Uncover Properties of the Substrate, P. Egberts, p. 62	Using Machine Learning Algorithms to Relate the Surface Topography of As-Built Surfaces to Additive Manufacturing Process Parameters, B. Raeymaekers, p. 64
4:30 pm – 5:00 pm	Strength from Weakness: Dynamicity in Biotribological Interfaces, W. Gregory Sawyer, p. 60	MXene Nanosheets Exhibiting Layer-Dependent Friction Properties, Eui-Sung Yoon, p. 62	How to Get to Big Data in Tribology? A Hands-on Example, N. Garabedian, p. 64
5:00 pm – 5:30 pm	Lubricant-Chemistry Kinetic Model of Boundary Lubrication by Oil Additives Using SOL, QM+MD, and Machine Learning, Z. Ye, p. 62	Nanoscale Friction of High Entropy Alloy Sulfide Thin Films in Comparison with Molybdenum Disulfide, G. Adabasi, p. 62	Panel Discussion
5:30 pm – 6:00 pm			
6:00 pm – 6:30 pm			

Session 1A | 101A

Lubrication Fundamentals I: Forecasting Trends

Session Chair: Mihir Patel, Chevron Oronite LLC, Richmond, CA

Session Vice Chair: Ramoun Mourhatch, Chevron Oronite LLC, Richmond, CA

8:00 am – 8:30 am

3833921: What Makes a Sulfur Compound Inactive versus Active? An Examination of Sulfur Compounds and its Effect on Lubrication

John Williams, Mark Harr, Dover Chemical, Dover, OH

It is well known in the lubricants field that sulfur, commonly used as an EP has two different compound types, active sulfur and inactive sulfur, where active sulfur stains and is corrosive to yellow metals and inactive sulfur which does not stain nor corrode yellow metals. In this paper we seek to find out what makes the difference. At what sulfur chain length does sulfur become active? Does the cross linking make a difference on inactive vs active? In this paper and presentation, olefins and fatty acid esters will be sulfurized using a standard black sulfurizing process at varying molar amounts of sulfur vs 1 mole of the unsaturation. After sulfurizing the material, the various sulfur compounds will be separated using a LC-MS by Sulfur chain length amounts and by cross linkage and then checked using ASTM D0130-19 at 5% in 100 naphthenic oil by weight. From this study we will show at what sulfur chain number a sulfur compound becomes active and if cross linking is a factor.

8:30 am – 9:00 am

3835945: Sustainable Cooperation in the Lubricant Industry – A Transformation Towards a Circular and Sustainable Lubricant Value Chain!

Inga Herrmann, VSI Verband Schmierstoff-Industrie e.V., Hamburg, Hamburg, Germany

Sustainability is a key agenda item for the lubricants industry today and will remain so for decades to come. Without sustainable business models and corporate strategies, companies will find it difficult to remain competitive and thrive. Becoming climate neutral requires the responsible use of resources and environmental protection. The lubricants industry has a key role to play; lubricants are part of the solution, as they make a significant contribution by reducing friction, corrosion and wear, which in turn results in lower energy consumption, reduced greenhouse gas emissions and longer equipment life. Developing a common and meaningful methodology for calculating product carbon footprint is vital for the global lubricant industry to create a level playing field. Industry associations from all parts of the world are working together to develop a transparent and consistent methodology to allow the calculation and sharing of reliable and comparable data for finished lubricants.

9:00 am – 9:30 am

3823908: Challenges for Lubrication R&D in Future Powertrains Applications and Potential Solutions in Precompetitive Research

Christian Kunze, Dirk Arnold, Forschungsvereinigung Antriebstechnik e.V., Frankfurt, Germany

Ecological and economic challenges are changing the way lubricants and tribological systems will be developed, produced and applied. It is essential to know future requirements and address R&D demand. For this purpose, FVA uses the Technology Trend Radar and subsequent technology studies. These tools align the FVA research portfolio with relevant future topics and make this know-how available to its member companies to design future products and processes at an early stage. In Technology Trend Radar, mega trends are identified and checked for relevance to drivetrain industry. Trend studies ensure detailing of research demand. Out of this process, pre-competitive research projects are derived. Studies have been commissioned on e.g., Green Tech and bio-based lubricants. In parallel, concrete projects have been launched for future topics of lubricants and tribology. Results on bio-based lubricants, lubricants and coolants for e-mobility and new test and analysis methods will be covered.

9:30 am – 10:00 am

Open Slot

10:00 am – 10:30 am – Break

Session 1B | 101B

Rolling Element Bearings I

Session Chair: Kushagra Singh, Purdue University, West Lafayette, IN

Session Vice Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

8:00 am – 8:30 am

3931726: Experimental Validation and Comparison of Friction Torque Models for Rolling Element Bearings

Josephine Kelley, Gerhard Poll, Leibniz University Hannover, Garbsen, Germany

A bearing friction torque model that decomposes the total friction torque of a rolling element bearing into several components is investigated; friction due to churning losses, sliding friction, hydrodynamic rolling friction, and hysteresis friction are modelled individually. For some of these submodels, several modelling approaches have been proposed in literature, sometimes with very different results. In particular, modelling choices for the churning losses and hydrodynamic rolling friction have a big impact on the final estimated bearing torque value. A comprehensive comparison is presented, using nearly 1600 measured bearing torque values from literature. The bearing type, size, loading, speed, and lubricant are varied, enabling an extensive evaluation of the submodels.

8:30 am – 9:00 am

3813088: Cryogenic Test and Evaluation of Pin-on-Disk with the Various Cage Materials for Solid Lubricated Bearings

Wonil Kwak, Yeongdo Lee, Jeonkook Lee, Yongbok Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea

In the interaction of solid lubrication, the friction mechanism can determine the effect on the bearing performance of cryogenic fluids (liquid nitrogen) through tribometer experiments. In this study, friction mechanism analysis was performed considering the coupling of bearing friction characteristics and fluid dynamics by the dynamic interactions between the bearing components. In addition, in order to improve friction performance in a cryogenic environment, a pin-on-disk test was conducted according to various composite materials. The purpose of this study is to understand the correlation between parameters affecting the improvement of solid lubrication performance in cryogenic fluid environments and diagnostic parameters for predicting the lifetime. In particular, this paper proposes a dimensionless friction coefficient classification factor that can satisfy an appropriate wear rate and predict its lifetime for the operating stability of ball bearings.

9:00 am – 9:30 am

3813004: Augmented Lubricant Replenishment for Rolling Bearings at Limited Lubricant Supply Conditions

Patrick Pat-lam Wong, City University of Hong Kong, Kowloon, Hong Kong

Regulating the lubricant supply to a bearing can reduce viscous friction, that may be lessened or withdrawn by lowering the lubrication effect. Thus, to better use the available lubricant in a bearing is important. This work presents a wettability surface pattern: an untreated oleophilic lubrication track sandwiched by oleophobic surfaces. Droplet transportation on the pattern surface was simulated. A liquid droplet fell to the centerline of the track. It expanded along the track till equilibrium. On the oleophobic regions, it retreated after a maximum spreading distance was attained. The liquid flow towards the central track is due to the wettability difference. It is good to the replenishment for bearing lubrication. The derived surface pattern was implemented on ball bearing raceways. These replenishment-augmented rolling bearings were tested. They attained low bearing friction at limited lubricant supply, due to the improved replenishment by the wettability-patterned raceway.

9:30 am – 10:00 am

3833954: An Improved Dynamic Bearing Model Considering Cage Lubrication

Thomas Russell, Farshid Sadeghi, Purdue University, West Lafayette, IN

A dynamic bearing model for deep groove ball bearings was developed to investigate the influence of oil lubrication & cage design on the motion of bearing components (i.e., bearing raceways, balls, and cage) and overall bearing friction. The effects of cage lubrication were included in the dynamic simulation with both a local cage pocket friction model and a global cage drag loss model. The local pocket friction model solves for the state of starved, hydrodynamic lubrication inside of each cage pocket to capture drag torque and dynamic behavior. Additionally, relations derived from a regression analysis on a series of CFD simulations are used to describe the global drag force on the cage due to lubricant churning inside of the bearing cavity. Results from the dynamic bearing model are used to investigate the frictional contribution of cage geometries as a function of bearing operating conditions.

10:00 am – 10:30 am – Break

Session 1C | 102A

Sustainable Power Generation I

Session Chair: Matthew Hobbs, EPT, Calgary, Alberta, Canada

Session Vice Chair: Elaine Hepley, POLARIS Laboratories, Indianapolis, IN

Session Starts at 8:30 am

8:30 am – 9:00 am

3812250: Towards an Accelerated Protocol for the Evaluation of Solar Cells

Emmanouil Georgiou, Angelos Koutsomichalis, Hellenic Air-Force Academy, Athens, Greece; Dirk Drees, Lais Lopes, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Tom Van Der Donck, Jean-Pierre Celis, KU Leuven, Leuven, Belgium

Solar cells are expected to operate for 20-30 years. However, due to the synergism of thermal cycles and vibrations, wear phenomena can occur, especially at the tube connections. In this work we attempt to establish a test protocol for the characterization of the wear degradation of solar selective coatings. As a first step the dominant wear mechanisms were identified and then different test methods were applied to validate these mechanisms on the lab-scale. In particular, three main test-approaches were used: (a.) reciprocating sliding tests at the meso load to simulate localized scratching of the antireflection nano-layer, (b.) reciprocating sliding tests at higher temperatures to simulate the effect of thermal cycling which leads to the expansion of the tube and (c.) fretting mode II tests caused by vibrations. Based on the results, a better understanding of the failure mechanisms can be obtained, which we hope that can be utilized to further improve the quality and lifetime of solar cells.

9:00 am – 9:30 am

3833897: Advances in Varnish Condition Monitoring

Elaine Hepley, POLARIS Laboratories, Indianapolis, IN

When varnish formations in the oil reach a saturation point, the resulting deposits can be detrimental to the operating equipment and drastically reduce the overall service life of the lubricant. Condition monitoring is a well-known tool for evaluating the system's health and preventing varnish from causing a critical loss in fundamental lubricant design properties such as water separability and inhibiting corrosion, foam, and air release, and, most importantly, maintaining component longevity and uptime. This informative session will explore traditional varnish load monitoring techniques and how, paired with alternative analysis methodologies can provide insightful correlations into soluble and insoluble degradation by-products, L*a*b values, and more – identifying the varnish stage and type can be an invaluable aid to prevent critical agglomeration levels and influence what mitigation methods may be best to effectively eliminate varnish and keep systems operating optimally.

9:30 am – 10:00 am

3830424: Sustainable Aeroderivative Gas Turbine Operation Through Lubricant Chemistry Management

Matthew Hobbs, EPT, Calgary, Alberta, Canada

Aeroderivative gas turbines (GTs) are the most efficient heat engines ever developed. On their own, they have efficiencies on the order of 45%, however, this can be increased to 80% in a cogen arrangement. With efficiencies well above those of industrial GTs, aeroderivative use is becoming more important to meet rising demands sustainably. Moreover, their fast-start ability makes these GTs appealing as peakers that are relied on when renewable output is inadequate. While aeroderivative GTs are efficient, jet lube monitoring and maintenance practices lag behind those of industrial GT lubricants. Indeed, most jet oil programs neglect the application's primary cause of failure: inadequate management of the GT's lifeblood: it's oil. Since maintenance and sustainability go hand-in-hand, methods for better jet oil management can further reduce the impact of aeroderivative GTs. Specifically, lubricant chemistry management allows aeroderivative users to produce power even more sustainably.

10:00 am – 10:30 am – Break

Session 1D | 102B

Materials Tribology I

Session Chair: Tomas Babuska, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair: Faysal Haque, Miami University, Oxford, OH

8:00 am – 8:30 am

3849839: Orientation Controls Tribological Performance of 3D-Printed Model Thermoplastics

Samsul Arfin Mahmood, Emily Guo, Amanda Sterling, Kyle Schulze, Auburn University, Auburn, AL

Recent studies on additive manufacturing show that mechanical properties can be altered in a controlled manner by adjusting the relationship between build orientation and the applied loading from the service. In this work, the effect of build orientation on the tribological properties of 3D-printed PLA – Polylactic acid and ABS- Acrylonitrile butadiene styrene is investigated. PLA and ABS samples are printed using material extrusion with three different build orientations. Tribological results show that variation in build direction relative to the sliding direction leads to anisotropic wear properties. The best wear properties are achieved when the layers are oriented orthogonally to the sliding direction. The coefficient of friction remains mostly unaffected. PLA samples demonstrate significantly better tribological properties compared to ABS. Varying the sliding speed between the interacting surfaces also affects the wear properties of both PLA and ABS.

8:30 am – 9:00 am

3814091: A Ready-to-Use Temperature Model for Polymer/Steel Contacts

Mitjan Kalin, University of Ljubljana, Ljubljana, Slovenia

This work focusses on development of a contact temperature model for polyoxymethylene (POM)/steel in contacts typical for many tribological model test, like pin-disc, with ambition for its use for contacts in real components of similar heat-sink volume. Two-step methodology consisted of (1.) combining the tribotests with measurement of heat flux along the polymer pin with the theoretical thermodynamic analyses to calculate the contact temperatures as a function of selected tribological parameters. In a second step, (2.) a model that predicts the contact temperatures based on contact-load parameters and the heat-sink volume used to remove the heat from the contact, and which is independent of contact geometry, was developed. Typical contact pressures (1.6 – 4.8 MPa) and sliding velocities (0.4 – 1.0 m/s) for pin-disc tests or small polymer gears were used to obtain a broad range of contact severity in terms of (pv), namely 0.6 – 4.8 MPa.m/s (8-fold increase).

9:00 am – 9:30 am

3831914: Characterizing Billiard Chalk in the Cue Tip-Cue Ball Interface

Alan Martin, The University of Sheffield, Leeds, West Yorkshire, United Kingdom

Billiards sports such as snooker and pool are a multimillion-dollar industry. Viewing figures from across the globe lead to revenues from ticket sales and broadcasting rights, meaning substantial tournament prizes for professionals. Sponsorship opportunities (of these events and of players) are driven by amateur interest in the sports, played at home and in more serious settings such as snooker clubs and sports bars. In billiards, chalk is added to the cue tip to increase friction between the tip and cue ball. The greater coefficient of friction allows a player to hit the cue ball off-center. This imparts spin on the cue ball, influencing where the cue ball will ultimately come to rest, following impact with a target ball or cushion. This is the true skill of the games; to be able to control where the cue-ball finishes in order to set up subsequent shots. However, the mechanics of the game, particularly the frictional mechanisms of chalk, are little understood, so will be discussed.

9:30 am – 10:00 am

3819733: Nanoscale Rate-and-State Friction, Atomic Insights Via Complex Sliding Protocols

John McClimon, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Khagendra Baral, Izabela Szlufarska, University of Wisconsin – Madison, Madison, WI; David Goldsby, University of Pennsylvania, Philadelphia, PA

Rate-and-state friction (RSF) describes the history-dependent friction seen in many materials. No single RSF equation adequately describes all RSF behavior. Our prior work shows that the predictions of one RSF law are obeyed in slide-hold-slide testing protocols for nanoscale silica-silica contacts. To interrogate the nanoscale RSF response in more detail, we have made modifications to the standard slide-hold-slide testing protocol which isolate discrete aspects of the response, such as removing the lateral stress during the hold to impose truly static ageing, variation of the speed before the hold to show that system memory can be retained across 100s of hold time, and quantifying the slip during the hold time to demonstrate "slip strengthening." The diversity of responses is inconsistent with any existing form of the RSF laws. Insight into the physics of the sometimes non-intuitive behavior is provided by kinetic Monte Carlo simulation of the interfacial bonding dynamics.

10:00 am – 10:30 am – Break

Session 1E | 102C

Condition Monitoring I

Session Chair: Alfredo Garcia, Luval SA, San Bernardo, Chile

Session Vice Chair: TBD

8:00 am – 8:30 am

3809926: A Hybrid Modeling Approach for Transferring Machine Learning Assisted Condition Monitoring of Rolling Bearings to Differing Machine Types

Christoph Bienefeld, Bosch, Renningen, Germany

Aiming towards reliability- and cost-optimized predictive maintenance strategies for rolling bearings, condition monitoring is an essential aspect. In this context, Machine Learning (ML) algorithms have a key role for interpreting real-time measurements. In the presented case, vibration data is used for condition monitoring of a fixed bearing type within a test bench environment. Given the current state of the art, transferring trained ML algorithms for condition monitoring to other types of machines is a major challenge. Re-training the algorithms for each individual machine type generates high effort in terms of additional measurements. Addressing that issue, this contribution will first explain the hurdles underlying transferability. Subsequently, some of these hurdles will be addressed using knowledge of structure-borne sound propagation within the machine. The resulting hybrid model incorporates a combination of physics-based and data-driven methods.

8:30 am – 9:00 am

3812707: Application of Envelope Spectrum Analysis and Spectral Kurtosis to Diagnose Debris Fault in Bearing using Acoustic Signals

Henry Omoregbee, University of Lagos, Nigeria, Lagos, Nigeria; Mabel Olanipekun, Tshwane University of Technology, Pretoria, Gauteng, South Africa; Bright Edward, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

Debris fault diagnosis based on acoustic signals in rolling element bearing running at low speed and high radial loads are more of low amplitudes, particularly in the case of debris faults whose signals necessitate high sensitivity analyses. As the rollers in the bearing rolls over debris trapped in grease used to lubricate the bearings, the envelope signal created by amplitude demodulation carries additional diagnostic information that is not available through ordinary spectrum analysis of the raw signal. The kurtosis value obtained for three different scenarios (debris induced, outer crack induced and a normal good bearing) couldn't be used to easily identify whether the used bearings were defective or not. It was established in this work that the envelope spectrum analysis detected the fault signature and its harmonics induced in the debris bearings when bandpass filtering of the raw signal with the frequency band specified by kurtogram and spectral kurtosis was made.

9:00 am – 9:30 am

3841570: Anomaly Detection Methodology for Centrifugal Compressors and Steam Turbines

Manish Khandelwal, Sandeep Kogge, L&T Technology Services, Bengaluru, India

Steam turbine and Compressors are critical equipment in a chemical process plant whose failure may result in even catastrophic losses. A reliability plan should be implemented which helps to maximize production value by implementing successful asset maintenance. In this paper, a data-driven integrated framework for health prognostics for steam turbines and compressors with the objective of detecting anomalies at an early stage. Anomaly detection refers to detecting data points, events, or behavior that do not comply with expected or normal behavior. This paper proposes a method for increasing the transparency and explain ability of anomaly detection to indicate which parts of a system contribute to the deviation from expected behavior. The results show that the proposed method detect abnormal behavior in Steam turbines and compressors accurately and reliably and indicate why it deviates. Historical examples of similar faults are not required for the proposed approach to detect faults.

9:30 am – 10:00 am

3806620: The Opportunities of Rolling Bearing Impedance Signal Analysis for Condition Monitoring

Florian Michael Becker-Dombrowsky, Technical University of Darmstadt, Darmstadt, Hesse, Germany

Condition monitoring of technical systems has an increasing importance for the reduction of downtimes based on unplanned breakdowns. Bearing damages lead to a high number of machine failures. State of the art is the indirect bearing observation by vibration or component temperature measurement. Measuring the electrical bearing impedance in situ has the ability to get information about bearing revolution speed and bearing loads. The damage detection and localization in the bearing is also possible, like early research could show. Here, the impedance signal of five fatigue tests is investigated using individual feature selection. The feature behavior is analyzed and explained, it can be shown that the three different bearing operational time phases can be differentiated by analyzing the signal features. Explainable features show a significant change in their behavior before the occurrence of initial damages even minutes before the vibration signals of the test rig vary from normal state.

10:00 am – 10:30 am – Break

Session 1G | 103B

Nonferrous Metals I

Session Chair: Tom Oleksiak, Quaker Houghton, Oswego, IL

Session Vice Chair: Grigor Bantchev, USDA/ARS/NCAUR, Peoria, IL

8:00 am – 8:30 am

3833550: Emulsions for Aluminum Hot Rolling: Which Droplet Size Distribution is Beneficial to Lubricity?

Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

Aluminium is usually hot rolled thanks to an oil-in-water emulsion with typical oil concentration being 1-10%. The emulsion stability relies on chemical (surfactant) and mechanical (stirring) actions. The surfactants create specific oil droplets dispersed in the water phase, depending on their affinity with oil and water (HLB) and the surfactant mix selected. Consequently, the particle size distribution can be mono- or multimodal, with variable droplet sizes. To what extent does the lubricity of the emulsion depend on such oil droplet size distribution? This paper investigates the relation between tribological performance and oil droplets population in the emulsion, hence emulsion stability. Various stability tests are carried out (light scattering, diffractometry) to perform deep analysis of how the oil droplets behave in emulsion. The destabilization phenomena help to explain how the oil film is created in the roll bite to ensure best lubricity.

8:30 am – 9:00 am

3811844: Additives for High Lubricity Fully Synthetic Aluminum Machining Formulations

Tiffany Meyers, Steffen Glaenzer, Clariant Corporation, Mount Holly, NC

Metalworking fluid chemistry is ever evolving and changing due to the operation severity, increased nonferrous metal production, and the need for sustainable additives. Metalworking fluid is exposed to various conditions and must withstand harsh conditions during the manufacturing and processing of these nonferrous materials (e.g., rolling, cutting, forming, grinding). Lubricity additives can vary with shape, size, and solubility, contributing to the overall fluid performance. Formulators are looking for additives that simultaneously deliver additional functionalities that help metalworking fluid address today's formulation challenges. This paper will focus on several polyalkylene glycol chemistries as lubricity improvers specific for water-based, oil-free metalworking formulations, and how they perform on nonferrous alloys.

9:00 am – 9:30 am

3831286: Correlations Between Two Methods for Cloud Point and Pour Point Determination of Biobased Materials

Grigor Bantchev, USDA/ARS/NCAUR, Peoria, IL

The ASTM methods D97 and D2500 are well accepted and widely used for measuring the pour points (PP) and cloud points (CP) of lubricants. However, these require relatively large volumes (50mL) of sample which can be problematic when screening a large number of lubricants during the early stages of lubricant candidate selection. The newer methods D5949 (PP) and D5773 (CP) require much smaller volumes (microliters) and are easier to perform. However, they are not currently as widely

accepted. In the current report, the CP and PP of ~40 biobased materials (estolides, isoestolides, their esters and vegetable oils) were measured by the two sets of ASTM methods and the results correlated. The correlations between the two methods were poor: r2=0.68 for PP and r2=0.60 for the CP; however, they could be improved by correction equation using the viscosity of the samples.

9:30 am – 10:00 am

3832150: Hot Mill Coolant Filtration Improvements

Andrea Knopp, Constellium, Ravenswood, WV

The purpose of this presentation is to discuss the path necessary to investigate filtration improvements on Hot Mill lubricants. This would begin in what data is important for a baseline, testing methods, filter paper types, and outcomes gained. This process is applied to both tandem and reversing mills. The ultimate goal is to provide the simplest path to make a process improvement savings, regardless of coolant type or metal production.

10:00 am – 10:30 am – Break

Session 1H | 103C

Commercial Marketing Forum I

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:30 am

3907383: Chevron Phillips – PAOs in Thermal Management Applications

Ken Hope, Tom Malinski, Chevron Phillips Chemical Company, The Woodlands, TX

PAOs are well known as synthetic base oils for lubrication having excellent properties at high and low temperature extremes. Heat transfer is becoming more important than ever and especially so for emerging applications in electric vehicles and computer architecture design. Thermal management in applications such as immersion cooling for data centers and electric vehicles requires considerable attention to the physical properties of the base oil and materials compatibility of components submerged in the base oil. This presentation will highlight the performance properties for good heat transfer, dielectric properties, and material compatibility of Synfluid® PAOs and the tests that are being used to evaluate potential fluids. Selecting the best fluid will aid energy reduction, sustainability, and equipment longevity.

8:30 am – 9:00 am

3901784: Huntsman – Amines for Fuel and Lube Applications

Haibo Zhao, Huntsman Corporation, The Woodlands, TX

Huntsman corporation is the world leader of the amine productions. Our ethylene amines and polyether amines are widely used as either key formulation components or additive building blocks for fuel and lube additives production. We will introduce our ethylene amines and polyether amines product portfolio and production capability in this presentation. We will also discuss how Huntsman amine products are used in the application of fuel deposit control agents, lube dispersants, friction modifiers and corrosion inhibitors.

9:00 am – 9:30 am

3905158: ANGUS Chemical Company – Addressing the Emerging Environmental and Performance Challenges of Tomorrow with ANGUS' Multifunctional Additives

Min Chen, ANGUS Chemical Company, Buffalo Grove, IL

Emerging trends in metalworking fluids are driving formulators toward additives that provide high performance while meeting complex sustainability goals. From developing multi-metal formulations that reduce waste to increasing use of bio-based raw materials in formulations compatible with next-gen machinery, ANGUS has the tools to help formulators address evolving metalworking fluids requirements. ANGUS' multifunctional CORRGUARD™ neutralizers, ALKATERGE™ emulsifiers and DMAMP™ corrosion inhibitors are proven to deliver performance and environmental benefits essential to the sustainable success of the global metalworking fluids industry. This commercial presentation will provide new perspectives on how the functionality, versatility and profile of ANGUS additives can improve the productivity and sustainability of tomorrow's metalworking fluids, even in the most demanding environments.

9:30 am – 10:00 am

3905948: Colonial Chemical: ColaCor 186: A Unique Core Carboxylic Acid for Corrosion Inhibitors

Steven Tang, Colonial Chemical Inc., South Pittsburg, TN

ColaCor 186 is a carboxylic acid closely mimicking the dibasic acid. Its unique structure enables its superior performance in corrosion protection and hard water tolerance to the conventional dibasic acids. In addition to ferrous protection, ColaCor 186 based amine carboxylates can provide protection for other metals. This presentation will be discussing on the key performance attributes and applications of ColaCor 186 and products derived from it.

10:00 am – 10:30 am – Break

Session 1I | 104A

Electric Vehicles I

Session Chair: Farrukh Qureshi, The Lubrizol Corporation, Wickcliffe, OH

Session Vice Chair: Peter Lee, Southwest Research Institute, San Antonio, TX

Session Starts at 8:30 am

8:30 am – 9:00 am

3816216: Electrical Behaviors of Tribocontacts in Association with Friction and Wear Properties as Key Concepts for Lubes in Electrified Powertrains

Mathias Woydt, MATRILUB, Berlin, Germany; Gregor Patzer, Optimol Instruments GmbH, Munich, Germany

Electrically powered vehicles with lithium-ion batteries or fuel cells are todays favored mainstream in politics about the mobility turnaround. With the use of rolling bearings, the high energy density in electrified powertrains and electrostatic fields induced by magnetic fields, arcing forms a type of damage that has received little attention to date. Beside the bulk electrical properties of fluids and greases, the resulting electrical properties of tribofilms represent a key issue. Hairpins in the stator are a hitherto underestimated source of tribological challenges, because its insulating lacker must be compatible with transmission and/or cooling fluids. Micro-vibrations of hairpins bring the risk of fretting wear and

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short circuits. This presentation provides an overview of the resulting tribological and electrical properties of tribofilms, materials and fluids used in electrified drive trains, and how these can already be tribometrically tested in practice on a laboratory scale.

9:00 am – 9:30 am

3815343: Can Conventional ATFs be Used Safely in Electrified Transmissions?

Alejandro García Tuero, Noelia Rivera Rellán, Eduardo Rodríguez Ordóñez, Rubén González Rodríguez, José Luis Viesca Rodríguez, University of Oviedo, Gijón, Asturias, Spain

The position of the electric motor inside the transmission in hybrid electric vehicles (HEV) put it in contact with the automatic transmission fluid (ATF). For that reason, the ATF has additional electric requirements. In this work, the electrical compatibility of three different commercial ATFs is tested by measuring electrical conductivity, resistivity, permittivity, dielectric dissipation factor and breakdown voltage, and their tribological performance was studied through Stribeck curves, traction, and reciprocating tests. The original additive concentration was modified to higher and lower concentrations to check the impact on electrical compatibility and tribological properties. The results showed that, although the electrical conductivity increases with higher additives concentration, the ATFs remained compatible and the dielectric properties were also good for HEVs. Simultaneously, the tribological performance of these ATFs was improved at higher additive concentration.

9:30 am – 10:00 am

3840017: Development of Test Methods and Fluid Durability Study in Electrified Drivetrains

Cole Hudson, 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 serves as an update to this ongoing project in which a Chevy Bolt, Toyota RAV4 Prime Hybrid, and Hyundai Ioniq5 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 analyses, and operational data will be presented from all three programs.

10:00 am – 10:30 am – Break

Authors and Presenters Invited to Attend Speakers Breakfast

Lead authors and education course instructors are invited to the Speakers Breakfast: **Sunday through Thursday, May 21-25 (7:00 am – 8:00 am)** in the Grand Ballroom to meet with session and paper solicitation chairs (PSCs) for a continental breakfast on the days of their presentations. This is a great time to review the session schedule and note any last-minute changes. Speakers should plan on attending.

Session 1K | 201A

Metalworking Fluids I

Session Chair: Kevin Saunderson, BP Lubricants USA Inc., Dousman, WI

Session Vice Chair: Karen Harrington, Fuchs Lubricants Company, Harvey, IL

8:00 am – 8:30 am

3809282: Improving Metalworking Fluid Efficiency by Creating Hydrophilic Protective Barriers

Volker Demel, Matthias Reihmann, Gelita AG, Eberbach, Baden-Württemberg, Germany

With increasing costs for energy, raw materials and waste disposal, efficiency of processes and metalworking fluids becomes an ever more relevant factor. Following this trend, it's important to reduce downtime due to pipe clogging, deposits in the machines, as well as reduced drag out and support tool life. In this talk we will present results of adding natural hydroxyproline rich proteins (HRPs) to water miscible metalworking fluids, which show positive effects in this regard. It is observed that HRPs build nano-meter thin layers on metals, glass, and plastics – forming a hydrophilic, protective barrier against hydrophobic deposits such as lime soaps, resins or sulphonates. The machine centers stay longer clean and are easier to flush, leading to less energy consumption and downtime. The same mechanism prevents the oleophilic phase of a metalworking fluid to stick to the work pieces, reducing drag out.

8:30 am – 9:00 am

3811097: Overcoming Metalworking Fluid Instability: Beyond HLB

Hoon Kim, Michael Creamer, Zschimmer & Schwarz US, Gordon, GA

Instability of MWF typically prompted by change in water hardness, temperature, shear force, chemical or microbial decomposition of emulsifiers & contamination. Since instable emulsion can deteriorate MWF performances and detrimentally affect the product quality, durability & reliability, the emulsion stability has been one of the key elements to ensure MWF efficiency. Having said that, optimal emulsifier selection plays a crucial role in maintaining robust emulsion stability and adds many beneficial impacts on MWF quality such as better resistance to hard water, lower risk of foaming, and desirable functions of other additives. Along this line, two key parameters for choosing correct emulsifiers have been investigated in terms of chemical structures, HLB (Hydrophilic Lipophilic Balance) value and CPP (Critical Packing Parameter). In this presentation, we will introduce useful structure-property-performance relationships of various surfactants to optimize product performances & quality.

9:00 am – 9:30 am

3831459: A Novel Way to Measure Stability and Shelf-Life of a Metalworking Fluid Formulation

Ravinder Elupula, Formulaction, Piscataway, NJ

Metalworking fluids (MWFs) are engineered fluids made to optimize metalworking operations as rolling, drawing, grinding, cutting. They are complex formulations with multiple purposes: reducing friction, mitigate heating degradation, flush away residues, protect from corrosion, achieve desired surface finish. MWF formulations can contain tens of ingredients, the major one being oil, water and emulsifiers supplemented by a large range of additive like corrosion inhibitors, lubricity additives, defoamers, biocides, anti-mist agents, dyes, extreme pressure agent, metal deactivators, wettings agents, antioxidants. As a result, optimization of MWF is elevated at the level of science and stability is a critical parameter to be probed at every stage of the product line.

SEQENS Announces New Partnership For Lubricant Additives In The U.S.

To reinforce its global presence, SEQENS is pleased to announce its new partnership with Univar Solutions. Through the new partnership, Univar Solutions will reliably distribute SEQENS lubricants additives in the U.S. and Canada.

For more than 50 years, SEQENS has supported its customers in the development and formulation of metalworking and protection fluids, and greases with a wide offering of technologies:

- Extreme pressure sulfurized additives
- Antiwear additives
- Emulsifiers
- Corrosion inhibitors
- Protection additives
- High tech greases

Univar Solutions | SEQENS

1K

9:30 am – 10:00 am

3833753: Surfactant Roles in Emulsifiable Oils

Robert Golden, Pilot Chemical Company, Cincinnati, OH

Surfactants are the essential components of emulsifiable oils. They have a preference for residing at interfaces: liquid/liquid, air/liquid, or solid/liquid. They are responsible for stabilizing drops of oil in water, water in oil, corrosion inhibition and foam. Their behavior has to be governed by a physical and consistent set of rules, but elucidating these rules is the real tricky part. There are numerous models for surfactant behavior, each based on some physical aspect, but none are complete, and their predictive capability is extremely limited. The largest deficiency for the metalworking fluid industry is the lack of calculable predictability of a mixed surfactant system. Proposed here is a model outline meant to explain some of the interesting and useful properties for emulsifiable oils, and characterize some of the physical attributes that, if they could be quantified, result in a means to calculate, predict, and find the optimal performance.

10:00 am – 10:30 am – Break

Session 1M | 202A

Herbert S. Cheng Memorial Symposium

Challenges in Lubrication and Tribology Modeling I

Session Chair: Q. Jane Wang, Northwestern University, Evanston, IL

Session Vice Chair: TBD

This symposium invites presentations to honor Professor Herbert S. Cheng, discussing achievements in more than four decades of the Patir-Cheng average flow model and challenges in modeling lubrication and tribology facing the future technology developments. Symposium Starts at 8:30 am.

8:30 am – 9:00 am

3884945: Homogenization, HMM and Patir & Cheng: The Method that Changed the Game

Andreas Almqvist, Roland Larsson, Peter Wall, Luleå University of Technology, Luleå, Sweden; Greg de Boer, University of Leeds, Leeds, United Kingdom

It is not an exaggeration to say that the method addressing the mixed-lubrication problem introduced by Patir and Cheng (P&C) in the late 1970s was revolutionary. With this novel method, it became possible to study the effect of surfaces of (more or less) arbitrary rough nature, while previous studies had been focusing on surfaces with more simplistic roughness features, such as longitudinal or transverse striated irregularities. The P&C method can be considered to belong to the group known as Heterogeneous Multiscale Methods (HMM), where the problem is divided into a few coupled but distinctly separable scales that can be considered sequentially. In this group of problems, the branch of mathematics known as Homogenization can also be included. This paper is devoted to the significant similarities, as well as differences, that exist between these methods.

9:00 am – 9:30 am

3891451: A Mixed Lubrication Model of Piston-on-Ring Contacts Considering Temperature Dependent Shear Thinning and Elastic-Plastic Contact

Robert Jackson, Nolan Chu, Auburn University, Auburn, AL

This work develops a numerical methodology for predicting the performance of an automotive piston ring system by considering multiple scales of contact and lubrication mechanics. The finite element method will be used to model the mechanical deformations of the piston ring surfaces at large scales. A statistical rough surface method that renders asperities as elastic-plastic wavy surfaces predicts the solid contact area. The flow factor form of the Reynolds equation formulated for actual piston and ring surfaces will be solved to consider the effects of mixed-hydrodynamic lubrication. The lubricant viscosity depends both on temperature and shear rate. This will allow for the regimes of boundary, mixed and full-film lubrication to be considered. The model predicts friction for various loads and speeds that are then compared to experimental measurements. The results predict operation mostly in the mixed lubrication regime, but variation in friction with load, speed and temperature.

9:30 am – 10:00 am

3899130: From Photosynthetic Carbon Capture to Self-Healing Tribofilms

Yeau-Ren Jeng, National Chang Kung University, Tainan, Taiwan

The current mineral lubricants to mitigate friction are potentially creating as many problems as they are solving because mineral oils are as environmentally damaging as the additives used to enhance their performance. Therefore, new carbon-neutral solutions are required. Our solution is inspired by the fact that vegetable oil can create a functioning non-stick, low-friction surface on a Chinese wok by seasoning it at elevated temperatures. We optimize our vegetable oil formulations with soothing ingredients to spontaneously generate self-healing amorphous carbon (a-C) films while functioning as a high-performance lubricating system. As a result, our green formulations can outperform similar mineral-oil formulations under extreme lubricating conditions.

10:00 am – 10:30 am – Break

Exhibitor Appreciation Hour and Evonik Raffle

Two hours of dedicated exhibit time will occur at this year's trade show:

Monday, May 22 and Tuesday, May 23 (3:00 pm – 4:00 pm) in Hall B. All other annual meeting activities will be closed during this time, and refreshments will be served! Come view the industry's newest products and technologies from more than 100 companies.

As part of the **Exhibitor Appreciation Hour,** Evonik is hosting raffles on Monday and Tuesday, May 22 and 23, at 3:30 pm in the exhibit hall. You must be present at Evonik **(Booth 205)** at the time of drawing to win. Evonik is raffling two Yeti soft coolers.


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Session 1N | 202B

Nanotribology I

Session Chair: Wai Oo, University of California, Merced, Merced, CA

Session Vice Chair: TBD

8:00 am – 8:30 am

3834331: Nano-scale Friction of Graphitic Surfaces in n-hexadecane

Behnoosh Sattari Baboukani, University of California, Berkeley, Berkeley, CA; Zhijiang Ye, Miami University, Oxford, OH; Prathima Nalam, University at Buffalo, Buffalo, NY

Sliding-induced friction behavior of a single-asperity silica probe against few-layer graphene and bulk graphite is measured in n-hexadecane using an atomic force microscope (AFM). The load-dependent nanoscale friction measurements display friction hysteresis, i.e., higher friction forces during unloading of the contact than loading at a given normal load. Quasi-static force-separation curves identify four layers of n-hexadecane on graphitic surfaces. Molecular dynamic simulations illustrate that the solvated n-hexadecane molecules within the contact carry the probe load and determine the generated contact area, affecting friction hysteresis. Further, during AFM probe sliding, a molecular pile-up of n-hexadecane in front of the tip is observed. It has also been shown that the friction behavior of graphene changes by immersion time. n-hexadecane molecules diffuse between graphene and the supporting substrate and undergo a structural transition over time which impacts friction.

8:30 am – 9:00 am

3812927: AFM Cantilever Tip Radius Estimation Through Contact Resonance Force Spectroscopy

Thomas Mathias, Philip Egberts, University of Calgary, Calgary, Alberta, Canada

In Atomic Force Microscopy (AFM), the cantilever probe tip radius is a key parameter when characterizing the system's response. Currently, several measurement techniques are utilized to directly determine the cantilever tip radius. However, these techniques all have shortcomings including higher equipment costs, complexity, and increased testing time. In this paper a new procedure to estimate the tip radius is explored incorporating the technique of contact resonance. This is accomplished first by measuring the frequency response spectrum of the cantilever when free and in contact with a sample. Then by applying cantilever contact resonance and contact mechanics models together the cantilever tip radius is estimated. Various models were included in this study considering changes in cantilever geometry, damping, and surface adhesion. This procedure was applied to several cantilever probe types and surface materials including contact, tapping, and colloid particle probes of many sizes.

9:00 am – 9:30 am

3833291: The Effects of -H and -OH Termination on Adhesion, Friction, and Wear of Silicon-Silicon Interfaces: A Molecular Dynamics Investigation

Judith Harrison, US Naval Academy, Annapolis, MD; Robert Carpick, University of Pennsylvania, Philadelphia, PA; J. David Schall, North Carolina AT&T University, Greensboro, NC

The chemistry at contacting interfaces strongly affects adhesion and friction, but we lack understanding of the controlling atomistic mechanisms. For silicon, this creates challenges and opportunities for technologies including nano/micro-electromechanical systems, semiconductor manufacturing, and flexible electronics. To develop insights for such systems, the work of adhesion for Si-Si interface was examined using reactive molecular dynamics. Simulated systems were composed of two Si(111) surfaces with varying levels of surface termination with equal mixtures of randomly placed -H and -OH groups. These were compared with fully terminated surfaces with varying ratios of -OH and -H. Adhesion was affected by non-bonded, bonded, and polar interactions. The bonding mechanisms and their effect on friction as a function of termination and load were also examined. Simulation results are compared to experimental results from in-situ transmission electron microscopy-based nanoindentation.

9:30 am – 10:00 am

3810859: Unique Frictional Characteristics of Germanium-based Nanofilm

Chaochen Xu, University of Calgary, Calgary, Alberta, Canada

A new class of two-dimensional (2D) materials based on germanium, are potential candidates for applications as polarization photodetectors, semiconductors and field effect transistors due to their narrow band gap, high carrier mobility and the typical in-plane anisotropic layered structure. While their electronic properties have been examined, limited experimental study of their mechanical properties has been conducted to assess them for this application in comparison to conventional 2D materials. In this study, the friction behavior of supported GeAs was studied by AFM and MD simulation. A novel inverse-layer-dependent friction behavior was found, where larger friction was observed with thicker GeAs coverage. This trend is unlike the layer-dependent friction observed on conventional 2D materials, where friction decreases with increasing coverage. The underlying mechanism is likely linked to its unique electronical performance.

10:00 am – 10:30 am – Break

Session 1O | 202C

AI and Machine Learning I

Session Chair: Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

Session Vice Chair: Prathima Nalam, University at Buffalo, Buffalo, NY

8:00 am – 9:00 am

3834306: Deep Learning Data-Driven Model for Coefficient of Friction Prediction of Lubricated Tribo-pairs

Maria Victoria Granja Oramas, C. Fred Higgs III, Rice University, Houston, TX

The prediction of tribological behavior based on output data streams is often considered an empirical science since it is difficult to fully describe underlying processes with mathematical terms, e.g., by differential equations. Machine Learning provide opportunities to elucidate the relationship between operating and performance parameters in complex tribological processes while uncovering emergent patterns. This project aims to develop a deep learning data-driven model capable of predicting the coefficient of friction(COF) of lubricated tribosystems. Modeling capabilities that can accurately predict the coefficient of friction across three major lubrication regimes – boundary, mixed and hydrodynamic – are allusive. Extensive data collection will be conducted by running tribological tests covering the entire range of the Stribeck curve, and efforts are made to train the model. Once the model is optimized, it could be deployed to predict the COF of any lubricated ball-on-flat tribosystem.

9:00 am – 9:30 am

3823140: Towards the Prediction of EHL Film Thickness Parameters by Machine Learning Approaches

Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile

Non-dimensional similarity groups and analytically solvable proximity equations can be used to estimate integral fluid film parameters of elastohydrodynamically lubricated (EHL) contacts. In this contribution, it is demonstrated that machine learning (ML) approaches (support vector machines, Gaussian process regressions, and artificial neural networks) can predict film parameters more efficiently and with higher accuracy and flexibility compared to sophisticated EHL simulations and analytically solvable proximity equations, respectively. It is verified that the trained ML approaches can achieve coefficients of determination above 0.99, whereby the size of the data base, the hyperparameters and the architecture influence the prediction accuracy. It can be assumed that ML approaches will boost the prediction of EHL parameters and traction losses in multibody system dynamics simulations.

9:30 am – 10:00 am

3834040: Digitalization: Bringing a "Frictionless" Future Closer to Reality

Sravani Gullapalli, Edward Malisa, Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX; Dillawar Syed, Shell Global Solutions (UK), London, United Kingdom

Reducing friction losses in machines is coveted as it translates to reduced wear, improved fuel and engine efficiency, energy savings and improved sustainability performance. Mini Traction Machine (MTM) measures frictional properties of lubricants under a wide range of rolling and sliding conditions. This test generates extensive data points in unstructured data format. Scientists spend enormous time on extraction, data analysis and data transformation of the raw MTM output. In addition, there is no visibility of historical tests. The SPARK team automated the conversion of unstructured data to structured content leveraging technologies such as cloud storage and natural language processing. This conversion in turn "made accessible" historic tribology data and enabled the creation of a centralized, searchable database, which reduces data duplicates, enables the comparison and ranking historically tested lubricants and drives easy data-driven insights.

10:00 am – 10:30 am – Break

Session 2A | 101A

Lubrication Fundamentals II: Marine Engines

Session Chair: Ashish Jha, Chevron, Richmond, CA

Session Vice Chair: Brendan Miller, Chevron Oronite Company, Richmond, CA

1:30 pm – 2:00 pm

3833984: Performance of Additives Improving Asphaltene Dispersancy in GII Base Stocks

Ashish Jha, Chevron, Richmond, CA

Growing use of GII base oils creates challenges in handling asphaltene deposits in Marine TPEO applications. Intrinsic properties of GII base oils dictate a more challenging environment for additives to work effectively toward asphaltenes compared to that in GI base oils. This presentation describes improvements made in asphaltene dispersancy in GII base oils. Parallel benefits in terms of reduced component interaction will also be presented.

2:00 pm – 2:30 pm

3819130: Experimental Evaluation on a Special Cylinder Oil Additive Package Applied in Blender on Shipboard

Jie Zhang, Li Kai, Chen Ligong, Tao Yida, Richful Lube Additive Co. Ltd., Xinxiang, Henan, China

According to IMO 2020 regulation, two options of cylinder oil need to be chosen by shipowners. One is 40BN to fit low sulfur fuels. The other is 70BN or 100BN to fit high sulfur fuels with scrubber system. Electronic control instead of mechanical mode enhances the clean ability and lifetime for system oil due to its function of cooling in piston crown and lubricating for servo system. Blender on shipboard can constantly consume used system oil to blend cylinder oil and fresh oil is replenished into crankcase. So, system oil gets refresh and components in crankcase become clean. In this study, we aim to evaluate the properties of this additive package by in-house simulating tests, such as Pressure scanning calorimetry, Caterpillar micro-Oxidation test, Hot tube tester, Panel coker tester, SRV, SEM and EDS. From the test results, we can conclude that the candidates additive show better capacities of deposit control and friction resistance comparing with the commercial references.

2:30 pm – 3:00 pm

3811850: Varnish Resistance Prediction Indicator (VRPI) for Group I-IV Lubricants

Joseph Fotue, TotalEnergies Marketing Cameroon, Douala, Cameroon

In recent years, industries have witnessed an increase in varnish-related problems. Varnish is one of the most harmful contaminants impacting lubrication systems severely and leading to component failures, unplanned shutdowns, and costly downtime. Varnish precipitation in a system is affected by operating conditions, the oil, and the environment. Responding to varnish with a suitable solution is critical. Many solutions exist to mitigate varnish in a system. However, since prevention is better than cure, the first line of defense is choosing an excellent varnish resistance lubricant. Is there an indicator that can show the lubricant's varnish resistance? If yes, this indicator will depend on oxidation resistance and product solvency. In this article, we propose a lubricant calculated parameter: VRPI (Varnish Resistance Prediction Indicator) useful to easily evaluate different formulations and to make better purchasing decisions.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3802552: Study of Tribological Contact Condition Using the Non-linear Behavior of Longitudinal Ultrasonic Waves

Saeid Taghizadeh, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

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

2A

4:30 pm – 5:00 pm

3833947: Reduction of Carbon Footprint and Maintenance of Oil Life through Performance Selection of Lube Oils

Ganesh Natrajan, Sara Rezaee, Aparna Bala, Ramaratnam Visweswaran, Viswa Group, Houston, TX

The International Maritime Organization has set a target to cut emissions by 50% in 2050 against the 2008 emission levels. Initiatives to cut carbon footprint with alternative fuels, and exhaust gas scrubbers have gained interest. This focal point of emission reduction from fuels eclipses some of the other potential approaches such as the contribution of selecting the right lube oil. The right lube oil not only helps in reducing emissions by lowering fuel consumption but also contributes to substantial monetary savings. Preliminary investigations showed that there could be as much as 10.7% in energy efficiency characteristics between oils of the same type and grade but differ in brands. This paper discusses the long-term benefits of selecting the right lube oil based on performance factors such as an oil's energy efficiency, ability to resist oxidation, amount of saturates & lower molecular weight fractions present in the oil, and its potential to deter deleterious contaminants.

5:00 pm – 5:30 pm

3812345: Accelerating the Development of Piston-Liner Tribology in Marine Diesel Engines Using Ultrasonic Transducers

Oliver Spenceley, University of Sheffield, Leeds, United Kingdom

Compliance to new and pending maritime emission legislation requires marine engines to operate at greater efficiency and reduce emissions. An increase in fuel efficiency and a reduction in emissions can be achieved simultaneously by minimizing excessive cylinder lubricant oil in the combustion chamber. A measurement system to define the oil film thickness (OFT) in real-time has been developed in order to optimize the cylinder lubricant oil feed rate, reducing parasitic energy loss, and minimizing emissions produced from the burning of excess oil. Ultrasound transducers were installed on the outside of the liner on a full-size marine engine test bed. The transducers emit ultrasonic pulses which reflect from the inner wall of the liner. As the piston passes by the reflection is recorded and used to deduce the OFT between ring and liner, as well as residual oil on the liner surface, it was shown that the minimum oil film thickness ranged from 2.5-10 µm as the rings passed the transducers.

5:30 pm – 6:00 pm

STLE New Members and Students Invited to Networking Reception

New STLE members and students are invited to a networking reception on **Sunday, May 21 (6:30 pm – 8:00 pm)** at Bogarts & Co. Please join us in welcoming new members of the STLE community and the next generation of tribologists for an evening of networking and great food.

This is a ticketed event for new members and students only!

Session 2B | **101B**

Rolling Element Bearings II

Session Chair: Kushagra Singh, Purdue University, West Lafayette, IN

Session Vice Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

1:30 pm – 2:00 pm

3812856: Contribution of Rolling Bearings to Improve Driving Range of Electric Vehicles

Jitesh Modi, Schaeffler Group USA, Troy, MI

Range anxiety has been a key challenge for the electric vehicles. Rolling bearings can provide a significant contribution to increase driving range through system understanding, effective analytical tools and application of innovative bearing solutions. Using advanced bearing steels, special heat treatments and surface coatings can help to enhance overall performance and driving efficiency of electric vehicles. On basis of discrete examples of innovative bearings, their optimized arrangements and holistic system design approach, the overall benefits of rolling bearings in electric vehicles are described.

2:00 pm – 2:30 pm

3831269: Influence of Bearing and System Design on CO_2 Emission Savings

Vasilios Bakolas, Philipp Rödel, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

In this paper, a series of parameters related to bearing designs will be compared to one another in the context of their energy efficiency and CO_2 emissions. Apart from parameters such as roughness and osculation, the effect that bord geometry, cage design and tolerances have on friction will be investigated. Furthermore, the effect that bearing installations have on the overall energy efficiency of a system will also be discussed to show that bearing optimization paired with system understanding for specific applications can lead to the optimum reduction of CO_2 emissions. A series of application designs will be evaluated, and the degree of optimization will be quantified.

2:30 pm – 3:00 pm

3812197: Influence of Form Deviated Bearing Seats on the Operating Behavior of Cylindrical Roller Bearings

Oliver Koch, Onur Atalay, RPTU, Kaiserslautern, Germany

There is a comprehensive set of standards and recommendations to design roller bearings in terms of tolerances. To avoid negative effects of the operating behavior of bearings the bearing manufacturers specify very precise tolerances for the bearing seats (IT4 … IT6). This leads of course to high manufacturing costs. But it is an open question if these precise tolerances are really necessary for a smooth operation of rolling bearings. Experimental studies of cylindrical roller bearings mounted on bearing seats with different waviness show a potential impact of the deviation on creeping of bearing rings. In addition, Multibody-Simulations (MBS) show that a certain waviness on the inner or outer raceway can generate a series of high energy pulses at a rate equal to the ball pass frequency relative to the inner or outer raceway. Because the inner ring is rotating the waves enter and leave the load zone causing a variation in the rolling element-raceway contact force.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

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2B

4:00 pm – 4:30 pm

3799607: Experimental and Analytical Investigation of Oil Flow in a Ball Bearing

Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN, Andreas Meinel, Hannes Grillenberger, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

This investigation aims to examine and visualize the oil flow inside a ball bearing. A counter-rotating ball bearing test rig was designed and developed such that both bearing races can be rotated simultaneously in opposite directions, allowing for observation of a single cage pocket in a stationary reference frame. The oil flow inside the bearing was analyzed using a high-speed camera and transparent cages. Bubble Image Velocimetry was used to track bubbles generated due to oil aeration and to study the flow inside the bearing. UV dye was used to observe oil starvation inside the cage pocket, which was influenced by raceway motion, oil fill level, cage pocket shape, and oil properties. Results from CFD models developed in Ansys Fluent corroborated well with the experimental results for oil flow. The current work provides the most detailed validation of a ball bearing CFD model to date, and the current modelling can be extended to investigate new cage designs.

4:30 pm – 5:00 pm

3810080: Experimental and Analytical Investigation of Angular Contact Ball Bearing Cage Pocket Lubrication

Saeed Aamer, Farshid Sadeghi, Purdue University, West Lafayette, IN, Andreas Meinel, Hannes Grillenberger, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

This study aims to investigate lubricant flow experimentally and analytically in a ball bearing cage. A custom bearing test apparatus, incorporating a transparent bearing cage (TBC), was developed to study lubricant flow within the cage for various ball speeds and cage positions relative to the ball. The TBC was manufactured based on the original bearing cage geometry and was positioned in the test apparatus, relative to the ball, using a precision XYZ table. A multiphase CFD model was developed to simulate the operating conditions of the test apparatus. The model results agreed well with the experimental trends. The results demonstrated that as the cage was moved closer to the ball, lubrication conditions changed and fluid striated over the ball surface, resulting in greater air entrapment within the cage. Furthermore, increasing ball speed promoted starvation of lubricant supply to the cage. The CFD model also highlighted the role of surface tension in lubricant striation patterns.

5:00 pm – 5:30 pm

3831812: In Situ Measurement of Grease Churn within a Full-Scale Cylindrical Roller Bearing

William Gray, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, Sheffield, United Kingdom

Within this work a full-scale cylindrical roller bearing test rig was instrumented with ultrasonic piezoelectric elements, the waves of which are sensitive to lubricant film thickness, and can propagate through solid and liquid media, meaning direct access to the rolling contacts is not necessary. This means machinery modifications are kept to a minimum, and measurements are in-situ. Ultrasonic sensors were instrumented across the roller axis and results show that as fresh grease churns, the amount of free surface lubricant shortens towards the contact center, indicating starvation that is known to occur in greased bearings. However, this shortening is not consistent across the roller axis, and instead is more severe towards the roller-flange contacts. Additionally, films are not of a consistent thickness across the axis. The work findings give key insights into grease churn and reflow, as well as the potential for an ultrasonic approach to measure these parameters in field bearings.

5:30 pm – 6:00 pm

3830272: Long-Term Investigations of Different Bearing Configurations at Solid-Lubricated Rolling Bearings

SMichel Werner, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany; Stefan Emrich, Institut fur Oberflachen- und Schichtanalytik GmbH (IFOS), Kaiserslautern, Germany; Oliver Koch, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany; Michael Kopnarski, Institut fur Oberflachen- und Schichtanalytik GmbH (IFOS), Kaiserslautern, Germany

This contribution presents an investigation of solid-lubricated rolling bearings, which use a special, modified cage, where the cage pockets of the cage serve as a lubricant depot, besides the function of guiding the rolling elements. Investigations of the bearing system within the bearing service life are presented, and the torque curve, the wear mass and surface analyses are discussed. With respect to the elemental surface condition, the surfaces of the bearing rings and balls are examined with respect to the mass of the elements on them. Furthermore, service life investigations with different material pairings are presented, which show the service life achieved, the torque curve, the wear development and the surface analysis. The influence of the variation of cage material and ball coating on the wear of the bearing components is described, as well as how the distribution of the elements on the surface of selected tests differs.

Session 2C | 102A

Wind Turbine Tribology I

Session Chair: Ramesh Navaratnam, Patech Fine Chemicals, Dublin, OH

Session Vice Chair: Manish Patel, ExxonMobil Chemical Company, Spring, TX

Session Starts at 2 pm

2:00 pm – 2:30 pm

3833961: Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment Continued

Michael Blumenfeld, ExxonMobil Research & Engineering, Annandale, NJ; Kurtis Hartlen, Imperial Oil, Brights Grove, Ontario, Canada; Marianne Rodgers, Wind Energy Institute of Canada, Tignish, Prince Edward Island, Canada

Wind turbines are a demanding and cost-sensitive application where high availability and low maintenance costs are critical. One of the most frustrating issues a wind turbine operator can experience is a foaming gearbox lubricant, which can trip oil-level sensors and cause unexpected downtimes. These foaming events may result in lost revenue, messy clean-ups, and difficult troubleshooting. In this presentation, we will provide an update to the case study shared at the 2022 STLE Annual Meeting, documenting the impact of problematic gearbox foaming on the operation of a fleet of five 2MW turbines at the Wind Energy Institute of Canada. Results will be shared on identification of the proper flushing/conversion protocol for foaming gearboxes. Data showing the lubricant performance over time after different conversion strategies will also be presented. Finally, a discussion on the basis of foaming in lubricants will provide context for operators in solving and preventing future foam issues.

2:30 pm – 3:00 pm

3831417: Autonomously Triggered Application of Corrosion Preventing Lubricants

Sharon Flank, Jonathan Schupp, InfraTrac Inc., Smithsburg, MD

3D printing enables a novel approach to delivering lubricants autonomously in remote/hazardous locations. 3D printed microcontainers containing lubricant are affixed to the component potentially requiring maintenance. These storage shells are constructed of a durable polymer material. After lubricant is injected into the shells each is sealed with a second, less durable polymer. The capping polymer is selected for its sensitivity to one or more expected fault conditions (excess heat, friction, vibration, or acidity). Polymer #2 is printed atop the shells with a graduated depth leaving some shells thinly capped while others are covered more thickly. If a fault condition arises its presence acts to erode the fault-sensitive caps until the payload is released, starting with the shells that are most thinly capped. The self-lubrication/repair process is triggered autonomously by environmental conditions without action required by maintenance personnel.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3811827: Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound

Gary Nicholas, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom

A significant proportion of wind turbine gearbox bearings fail through axial cracking associated with white-etching cracks (WEC). Post-mortem examinations of these failed bearings usually involve destructive sectioning of the bearing to be analyzed under a microscope for the presence of WECs. For a large bearing component, this can be time consuming, especially when having to section blindly for WEC concentrated regions. In this work, ultrasound was trialed as a potential method to locate regions of high WEC concentrations which subsequently facilitates targeted sectioning at these regions of interest. WECs were generated within two bearing steel roller specimens using a MPR test rig with critical lubricants. A focused probe was used to transmit ultrasonic waves to the WEC concentrated specimen within a water bath. Amplitude as well as non-linear behavior of ultrasonic reflections were used to deduce the presence of cracks within the roller specimens.

4:30 pm – 5:00 pm

3811250: Sustainable Solutions for Wind Turbines

Mar Combarros, Marc Alumà, IQL, Castellgalí, Barcelona, Spain; Ariadna Emeric, Gerard Cañellas, Àngel Navarro, Taro Ehara, Industrial Química Lasem, Castellgalí, Spain

The gearbox of a wind power turbine must convert a low-speed high torque of the turbine blades to a low torque high-speed rotation of the generator shaft. Due to the low accessibility of the wind turbines specially while offshore, the oil change is a critical point. Therefore, an extended life-service of the lubricant is required and a high oxidative stability and hydrolytical stability are essential. Furthermore, micropitting is of extreme relevance because of its long-life expectation, unsteady wind, low velocities, high loads, and contamination. A sustainable alternative is presented offering an increased life-service and a reduced micropitting in comparison with a standard formulation. Sustainability is understood as a reduction of the environmental impact measured as an assessment of the life cycle of the product which includes: the origin of the raw materials, manufacturing, its performance and its biodegradability.

5:00 pm – 5:30 pm

3867432: Using a Rheometer to Test the Performance of Greases in an Oscillating Ball Bearing

Michael Bartram, The University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Oscillation in ball bearings can lead to failure in the form of either fretting or false brinelling. Grease lubrication can worsen the problem, as under certain oscillation conditions grease leads to starvation in the contact a lot more quickly than oil. This can cause problems for offshore wind turbines – pitch bearings typically operate under oscillating conditions. Due to their size (>5m diameter) and location (offshore), replacement is incredibly expensive. Therefore, extending the bearing life is desirable, which can be done by extending the life of the grease. Testing of grease on oscillating ball bearings is currently done either using a specialized rig, or using a simplified setup (e.g., ball-on-disc). However, many rheometers can precisely measure oscillating motion, and are already found in many labs. A custom attachment has been developed to mount a thrust bearing in a rheometer for use as a novel testing method to analyze the performance of greases under oscillating motion.

5:30 pm – 6:00 pm

Sustainable Power Generation & Wind Turbine Tribology Business Meeting

Session 2D | 102B

Materials Tribology II

Session Chair: John Curry, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair: Adam DeLong, Florida State University, Tallahassee, FL

1:30 pm – 2:00 pm

3813080: Effect of Diamond-Like Carbon Composition on Oxidation Reactivity and Friction

Seokhoon Jang, Seong Kim, Pennsylvania State University, State College, PA; Muztoba Rabbani, Ashlie Martini, University of California, Merced, Merced, CA

Although hydrogenated diamond-like carbon (HDLC) exhibits superlubricity and wear protection in inert conditions, its superlubricity depends on the sp^2/sp^3 carbon ratio and H content and is often lost due to surface oxidation. Therefore, understanding the dependence of HDLC composition on its oxidation reactivity and frictional behavior in O_2 and H_2O is important for the design of HDLC that provides superlubricity in oxidizing environments like humid air. However, investigating these relationships using ex-situ analyses of tribo-tested HDLC is challenging since HDLC surfaces are usually subject to air-oxidation after friction testing. Here, this issue is overcome by characterizing oxidation reactivity and friction of HDLC in O_2 and H_2O as a function of the composition of HDLC based on Raman spectroscopy, Langmuir-type kinetic analysis, and reactive molecular dynamics simulations.

2:00 pm – 2:30 pm

3848254: Process-Structure-Property Driven Development of High-Quality MoS_2 Coatings

Tomas Babuska, Michael Dugger, Steven Larson, John Curry, Sandia National Laboratories, Albuquerque, NM; Brandon Krick, Florida State University, Tallahassee, FL

Sputtered molybdenum disulfide (MoS_2) coatings have been used extensively in aerospace applications due to their ultra-low steady-state coefficients of friction (μss < 0.05) and low wear rates in inert environments. Developing MoS_2 coatings for demanding applications with predictable and reliable performance over time requires tuning the coating microstructure through process variations to promote high wear resistance, low μi, high density, and resistance to oxidation. Here we investigate the role of processing parameters such as argon pressure, bias voltage, and power density on resulting coating microstructural characteristics, tribological properties and oxidation resistance. Additionally, we investigate the batch variability and impact of processing variables on coating microstructure and properties for multiple deposition runs using parameters such as wear rate and hardness to quantify batch quality. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

2:30 pm – 3:00 pm

3832185: Quality Assurance Methods for MoS_2-Based Solid Lubricants

Michael Dugger, Mark Rodriguez, Sandia National Laboratories, Albuquerque, NM; Olivia Smithhisler, Michael Walsh, Theresa Pond, Kansas City National Security Campus, Kansas City, MO

Much research has been devoted to formulating MoS_2-based solid lubricants for use in extreme environment aerospace applications. The run-in and steady-state performance in different operating environments, as well as microstructure and aging behavior of films, are all important attributes to be considered when selecting a film for a particular application. However, rigorous characterization does not end once the specific coating has been identified. Large investments of time and money frequently involved with these applications warrant a rigorous quality assurance program to ensure that the solid lubricants will behave predictably for the service life of the mechanism. This presentation will describe one approach for insuring quality and reliable performance of MoS_2-based solid lubricant coatings over several years of production.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3832904: Wear and Corrosion Resistant Ni-SiC Coatings Fabricated by Adaptive Additive Manufacturing

Mohsen Tajedini, Peter Renner, Hong Liang, Texas A&M University, College Station, TX

To date, various coatings, have been employed to protect metallic alloys for many industrial applications, still, there is a need for a cost-effective and easy-fabricable coating method. In this presentation, we discuss about a new approach to applying Ni-SiC coating on steel substrates. The coatings were found to be highly corrosion and wear-resistive compared to bare steel. The wear rates were reduced by 80%, and the hardness was improved by more than twice. In electrochemical measurement, the corrosion current density of coatings was reduced by ~5 orders of magnitude compared with the reference sample, while the mass loss was only about 1% of steel substrate. Detailed discussion will be provided in this presentation.

4:30 pm – 5:00 pm

3833836: High-Frequency Reciprocating Tribological Assessment of MoVN-Cu Coating in Low-Viscosity Fuel Environments under Various Load, Temperature, and Sliding Velocity Conditions

Kelly Jacques, Asghar Shirani, Jesse Smith, Thomas Scharf, Andrey Voevodin, Samir Aouadi, Diana Berman,University of North Texas, Denton, TX; Scott Walck, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Osman Eryilmaz, Argonne National Laboratory, Lemont, IL

Inhibiting the tribological failure of mechanical assemblies which rely on fuels for lubrication is an obstacle to maintaining the lifetime of these systems with low-viscosity fuels. In the present study, a MoVN-Cu nanocomposite coating was tribologically evaluated in low viscosity fuels as a function of temperature, load, and sliding velocity conditions. Transmission electron microscopy was used to confirm the presence of nanoscale copper clusters within the coating which provide catalytic surfaces for the formation of tribofilms. Characterization of the MoVN-Cu worn surfaces confirmed the presence of an amorphous carbon-rich tribofilm. The tribological assessment of the MoVN-Cu coating reveals that the coefficient of friction decreased with increasing contact pressure. These findings suggest that MoVN-Cu is a promising protective coating for fuel-lubricated assemblies due to its adaptive ability to replenish lubricious tribofilms from hydrocarbon environments.

5:00 pm – 5:30 pm

3834225: Ultralow Wear PEALD Ternary Nitrides: Understanding Process-Structure-Property Relationships

Kylie Van Meter, Santiago Lazarte, Brandon Krick, Florida State University, Tallahassee, FL; Md. Chowdhury, Nicholas Strandwitz, Lehigh University, Bethlehem, PA; Mark Sowa, Veeco ALD, Waltham, MA; Alexander Kozen, University of Maryland, College Park, MD

Metal nitride coatings are frequently used in tribological applications due to their high wear resistance and friction reducing properties. Compared to traditional TiN films, multi-metal nitrides such as TiVN are found to be lower wear and friction and have higher oxidation resistance. Plasma-enhanced atomic layer deposition (PEALD) techniques enable atomic level thickness and composition control, allowing for the growth of thin (~100nm), conformal, conductive films at low deposition temperatures, where conventional CVD techniques are limited. These capabilities make PEALD nitride films candidates for microelectronics and MEMS/NEMS. Recently, PEALD ternary nitrides have achieved ultralow wear rates (K < 10-7 mm3/Nm). However, there lacks a fundamental understanding of the process-structure-property relationships in PEALD films. This work investigates the effects of deposition parameters, linking film structure, physical, mechanical, and chemical properties to tribological behavior.

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Session 2E | 102C

Condition Monitoring II

Session Chair: Kemberlee Snelling, Trico Corporation, Davison, MI
Session Vice Chair: TBD

1:30 pm – 2:00 pm

3801921: Lifetime Extension Strategies in Wind Turbine Using an OCM – Oil Condition Monitoring Program

Yesid Gomez, Adolfo Malaga, Jose Ignacio Ciria, Bureau Veritas Spain – OCM, Eibar, Gipuzkoa, Spain

Despite continuous innovation in wind turbine designs, lubrication systems, improvements in the properties of the different materials and in the formulations of the lubricants used, maintenance problems in all technologies persist, as a consequence of the fatigue of the components, or by external contamination that can cause accelerated wear of the components. Through the results of this study, we have been able to understand these modes of degradation, and above all, it has led us to propose new alternatives within the OCM – Oil Condition Monitoring programs that have allowed us to improve the early detection of possible failures and to be able to thus extend the useful life of the gearbox.

2:00 pm – 2:30 pm

3812603: Suggested Sampling Methods for In-Service Oil and Grease Lubricated Equipment

Victoria Bunchek, Raymond Dalley, Trico Corporation, Pewaukee, WI; Bernie Hall, Checkfluid, London, Ontario, Canada; Richard Wurzbach, MRG Laboratories, York, PA; George Staniewski, Tribology Consultant, Mississauga, Ontario, Canada

The purpose of this guide is to provide best practices for sampling in-service lubricant to decrease the variability between used oil analysis samples and improve the effectiveness of the data to make the resulting maintenance actions more meaningful and impactful as it relates to equipment safety, reliability, and lifespan. For the purposes of this guideline, equipment is divided into groups based on the techniques needed to satisfy sampling in general reservoirs; low, medium, and high pressure circulating lubricant systems; small reservoirs; hostile environments; and in grease-lubricated applications. In each category methods of basic, better, and best are provided. Equipment-specific direction is provided here to better serve anyone involved in taking used oil and grease samples or utilizing the data provided by such samples. The goal is to produce an evolving sampling guideline document for practicing end-users throughout the world.

2:30 pm – 3:00 pm

3836660: Optimizing Operational Savings with Fluid Analysis

Henry Neicamp, POLARIS Laboratories, Indianapolis, IN

The success of a fluid analysis program is usually measured by the amount of money, or the number of assets saved. Managing equipment in an organized manner is a vital step towards saving assets and money, so you can accurately track your return on investment. Embracing predictive maintenance technology is essential to maintaining healthy equipment, lowering maintenance time, and reducing costs. There are several actions maintenance professionals can take to maximize the value sampling provides. Learn hands-on tips for retrieving the optimum data to get the most actionable information from your management reports and sample report recommendations. Learn how to optimize finding the issues plaguing your fluid analysis program and use that information to increase your payoff several times.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3833723: A Sea Change in Fluid Analysis (a.k.a. Oil Analysis) Has Arrived

Jack Poley, CMI, Miami, FL

Fluid analysis dates to early 20th Century, when testing was primarily to determine lubricant viability; simple tests for contamination, e.g., water, precipitated solids, and degradation, e.g., viscosity; initiated by oil companies. Circa 1948, a railroad began testing for wear metals, like iron and copper. Wear metals testing signaled emphasis on the asset itself rather than the lubricant. This initial paradigm shift became the first CM discipline. There are now 8 paradigm shifts in fluid analysis, each adding scope and value, including onsite testing equivalency with remote brick and mortar labs, automated, artificial intelligence software to evaluate data and render advisories, full spectrum, large particle wear metals analysis and mixed-mode condition monitoring. These paradigms redefine and reinforce fluid analysis as the most valuable CM discipline for lubricated assets. Holistic Condition Monitoring – the 8th paradigm, leads the way.

4:30 pm – 5:00 pm

3833861: Using Oil Analysis to Identify Incorrect Bearing Lubrication

Evan Zabawski, Eurofins TestOil, Strongsville, OH

Far too often an oil change is performed on an asset when poor oil analysis results reveal high levels of wear, yet this does not truly address the root cause of the wear. Using an example of a bearing with high wear debris alarms but no alarms on the lubricant properties, see how to detect a common issue frequently found in bearing applications. Through guidance on proper interpretation techniques, discover how to interpret an oil analysis report to determine the causes of the alarmed data, identify commonly misdiagnosed root causes and decide on the best course of action.

5:00 pm – 5:30 pm

3833854: Using Oil Analysis to Determine Root Cause of an Overheated Gearbox

Evan Zabawski, Eurofins TestOil, Strongsville, OH

Determining what is wrong with a gearbox that runs hot but shows no signs of wear and the oil level is correct can be difficult. What if the oil properties are degrading, and the oil life is short? This session will show how to find commonly misdiagnosed or overlooked issues. A case study example of a medium-sized gearbox with a seemingly obvious lubricant failure will be presented to illustrate how oil analysis data can identify a lubricant selection problem. Learn how to apply this knowledge to future oil analysis reports to correctly diagnose the true root cause of an alarmed condition.

5:30 pm – 6:00 pm

Condition Monitoring Business Meeting

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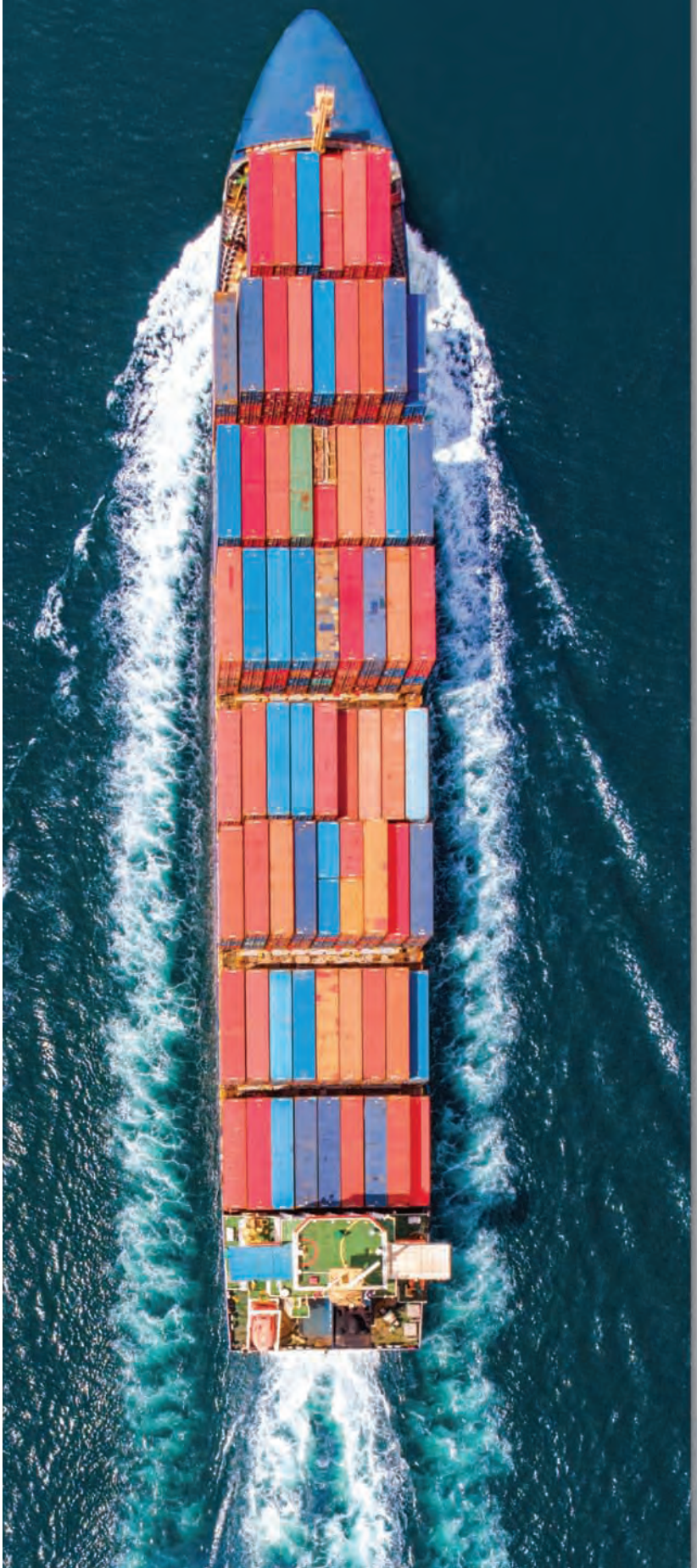

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Session 2F | 103A

Environmentally Friendly Fluids I

Session Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

Session Vice Chair: Daniel Garbark, Battelle Memorial Institute, Columbus, OH

1:30 pm – 2:00 pm

3811431: Global Fluid Trends

Edward Jones, Hangsterfer's Labs Inc., Mantua, NJ

Environmentally friendly fluids are sometimes simple and sometimes very complex formulas and technology. There exist several internationally and industry wide recognized governmental and independent agencies that greatly influence trends in acceptable technology. These agencies and their guidelines will be reviewed along with reasons why certain ingredients have or will become obsolete. The utilization of sustainable lubricant ingredients will also be reviewed and steps that need to be taken now. The presentation will contain information based on US, Canada, EU, UK, Japan and China governments, and industrial sectors that include aerospace, automotive, electronic, and medical. The impact on manufacturing processes will also be discussed. The choice to use environmentally friendly fluids should not be solely pushed on us by governments creating a reactive response, it goes beyond that and is a moral decision for the greater good and industry needs to be proactive with these decisions.

2:00 pm – 2:30 pm

3812469: Using the Life Cycle Assessment (LCA) Tool to Determine the Carbon Footprints of Castor Oil Derivatives

Travis Thompson, Biosynthetic Technologies, Indianapolis, IN

With concepts like sustainability and environmental performance gaining momentum in the lubricant industry, many companies are finally seeking ways to incorporate such characteristics into their product lines. While such terms seem simple at first glance, their subjective nature can make them difficult to understand and implement. One tool for navigating such concepts in a more objective way is the Life Cycle Assessment (LCA). A cradle-to-gate LCA has been conducted on a set of lubricant base oils and additives (castor oil derivatives), with an emphasis on understanding the true carbon footprint of these products. Direct and indirect emissions were considered, covering areas such as agriculture, feedstock transport, manufacturing, and waste management. This report provides a more comprehensive and objective measurement of the products' carbon footprints, allowing for a more quantitative understanding and a better basis for comparison to different types of products.

2:30 pm – 3:00 pm

3830719: Potential of Lubricant Base Oils from Microalgae

Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA; Derek Vardon, Robert McCormick, National Renewable Energy Laboratory, Golden, CO; John Scott, University of Illinois at Urbana-Champaign, Champaign, IL; Kenneth Doll, USDA-ARS-National Center for Agricultural Utilization Research, Peoria, IL; Timothy Strathmann, Colorado School of Mines, Golden, CO

Potential of hydrocarbons extracted from microalgal species Botryococcus braunii (B. braunii) race B were evaluated as a biobased lubricant. B. braunii biomass contains 55.6% (dry weight basis) extractable lipids comprised primarily of C31 and C33 botryococcenes. The extracted botryococcene oil displayed a remarkably high viscosity index (>300), favorable cold flow properties, marginally better oxidation stability than soybean oil, and tribological performance comparable to soybean oil and PAO oil. These lubricant properties can be ascribed to the high degree of branching present in C31 and C33 botryococcene molecules. The presentation will discuss the potential of botryococcene oil as biobased lubricant and feedstock for jet fuel.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3810970: Maximize Performance and Improve Sustainability Through Use of Group V Ester Technology

Gemma Stephenson, Kevin Duncan, Cargill, Snaith, United Kingdom

This paper will show that through using Group V ester base fluids, it is possible to achieve both high performance and excellent sustainability credentials in unison. Innovation and lifecycle thinking when designing products are crucial when engineering fluids with excellent intrinsic and extrinsic sustainability properties. Herein, we compare conventionally used base oils (Groups I–IV) with innovative ester technologies, looking not only at their inherent sustainability benefits, but also at their handprint – their tribological performance and benefits in-use, using testing that is applicable to both industrial and automotive applications. This paper will show that esters exhibit excellent friction reduction benefits when compared to Group I–IV counterparts. Studies have shown that this can relate to improved energy efficiency in tribological systems.

4:30 pm – 5:00 pm

3832044: Overcoming the High Viscosity Limitation of Readily Biodegradable EAL Base Fluid

Ramesh Navaratnam, Jerry Wu, Patech Fine Chemicals, Dublin, OH

As the demand of Environmentally Acceptable Lubricants (EALs) significantly grows, more and more industries that required heavy loading operation no longer satisfy with current EAL viscosity range. They need higher viscosity EAL for better wear protection. However, to achieve higher viscosity, the based fluids need to have higher molecular weight (MW) but as is well known that higher MW leads poor biodegradability. Therefore, how to make the high viscosity base fluid readily biodegradable will be a big challenge. In this presentation, we will show how we broke the viscosity limitation and successfully develop several high viscosity readily biodegradable base fluids. We will demonstrate the hydrolytic stability, lubricity, oxidation stability of these fluids. Since these types of fluids are sometimes used as viscosity modifiers or additive solubilizer, we will also show their compatibility with PAO, specifically in HEPR application.

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Session 2G | 103B

Nonferrous Metals II

Session Chair: Ariane Viat, Constellium Technology Center, Voreppe cedex, France

Session Vice Chair: Annie King, Total Energies, Linden, NJ

1:30 pm – 2:00 pm

3818372: Improving Aluminum Cold Mill Lubricant Performance with a Surface Active Agent

Thomas Oleksiak, Quaker Houghton, Oswego, IL

Cold rolling oils for rolling aluminum typically use a low viscosity base oil in combination with additives. Additives used in the process include fatty alcohols, fatty esters, and low levels of fatty acid. A surface-active agent was investigated as a means to improve efficiency of boundary lubricant additives. Aluminum wetting and surface energy experiments were used to analyze the effectiveness of this additive. Tribology testing will also be reported. Performance in the field will be analyzed relative to the observed surface chemistry and tribology analysis.

2:00 pm – 2:30 pm

3833171: Carbon Negative Liquid Hydrocarbons: Next Generation GTL Technology Commercializing in the US

William Anderson, ClearShift, Avon, IN

This presentation will discuss the technology and products being produced at demonstration plants of next generation GTL technology, making normal paraffins solvents and oils that are carbon negative. A combination of updated GTL technology called "Cool GTL" and SMR syngas production utilizing cutting-edge reverse water gas shift technology makes liquid hydrocarbons for the masses from man-made CO2. A fresh take on decarbonization. Looking to have a flagship plant operational in 2025/2026.

2:30 pm – 3:00 pm

3833991: Considerations for Changing Cold Rolling Base Oil

James Anglin, Allegheny Petroleum, Monroeville, PA

Most base oils for cold rolling of aluminum are relatively highly refined narrow cut hydrocarbon products. While making a change from one product to another might seem straightforward, many considerations are involved and the cost for a misstep can be high. Commercial, technical, and regulatory factors need to be considered and balanced against those for the incumbent. This presentation will delve into these considerations.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3848321: Influence of Raw Material Quality Variations on the In-service Performance of Aluminum Hot Rolling Oils

Josef Leimhofer, AMAG Rolling GmbH, Ranshofen, Austria

Oils for hot rolling of aluminum are complex mixtures of several raw materials, which are technical products and mixtures themselves. Their properties (e.g., emulsion stability, cooling properties, lubricity) are crucial for their use. Even minor changes in the composition of the oils can have severe consequences for the rolling process and therefore, the composition of these fluids is critical and thus, constantly monitored. Fluctuations in the composition of rolling oils can originate (e.g., from variations in the quality of the raw materials or from the formulation process). In this work, these variations in the quality of some raw materials for aluminum hot rolling oils are investigated and judged with respect to the impact on their in-service performance. For this purpose, standard analytical techniques are applied as well as highly sophisticated techniques (Nuclear Magnetic Resonance spectroscopy: NMR), and results of these investigations are presented.

4:30 pm – 5:30 pm

Nonferrous Metals Business Meeting

Session 2H | 103C

Commercial Marketing Forum II

Session Chair: TBD

Session Vice Chair: TBD

1:30 pm – 2 pm

3909095: Evonik Oil Additives: Novel Base Oil Technologies for Automotive Driveline Fluids

Justin Langston, Helmut Melchior, Gabriela Fedor, Thomas Schimmel, Evonik Oil Additives, Horsham, PA

Automotive gear oils must protect against wear, corrosion, and oxidation in severe operating conditions. Unlike conventional axle oils, electrical driveline fluids must meet additional requirements, such as thermal conductivity and copper corrosion. These requirements and extended fluid life expectations require high-performance components when formulating fluids. To reach viscosity targets and ensure stay-in-grade viscosity, formulators use shear-stable, high-viscosity base stocks in combination with low-viscosity base stocks. This paper will share the performance of novel synthetic high-viscosity base stocks. When incorporated in automotive gear oils and e-driveline fluid formulations, these novel base stocks offer unique solvency and low-temperature performance advantages. Furthermore, they work well with a wide range of base oils, providing formulation flexibility, and have low product carbon footprints, allowing for more sustainable formulations.

2:00 pm – 2:30 pm

3801832: LANXESS – Advances in H1 Food Grade Calcium Sulfonate Greases: A Continued Vision 20 Years On

Ross Dworet, LANXESS Corporation, Shelton, CT; Wayne Mackwood, Jesse Allan, Jeremy Brideau, LANXESS Canada Co./Cie, Toronto, Ontario, Canada

LANXESS was the first to introduce and produce H1, Food Grade, Calcium Sulfonate Complex (CSC) greases and has done so for the past 20 years. This presentation is an overview of our past as the leading technology developer to our latest developments. With the introduction of CSC greases to the food processing machinery lubrication market, industrial level performance had been introduced into this market. With exceptional performance in high humidity and varied conditions present in food manufacturing, CSC greases deliver, at the core of the technology, industrial formulated grease performance with the compliance of an H1 lubricant. A potential challenging regulatory situation has become a significant opportunity to push our grease performance to the next level of thermal and oxidative performance for longer life CSC greases for food manufacturing applications. This presentation will review the strengths of CSC grease in food grade applications with focus on current developments.

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2H

2:30 pm – 3:00 pm

3909050: The Lubrizol Corporation – Redefining Long Drain Hydraulic Fluids

Shubhamita Basu, The Lubrizol Corporation, Wickliffe, OH

Hydraulic fluids used in modern equipment are expected to withstand severe operating environments while protecting the hydraulic system components and preventing unforeseen downtime. In addition, the oil drain intervals (ODIs) are expected to be longer than ever to increase productivity and uptime while reducing waste and improving sustainability. However, there is no standard way to define long drain hydraulic fluids. TOST lifetime (ASTM D943 test), often used as an indicator of long ODI, is not correlated to real-world service life. In this talk, we propose an alternate way to define long drain hydraulic fluids that can provide a more comprehensive prediction of longer fluid life.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3909121: ExxonMobil – EHC 340 MAX™: Elevating Extra Heavy Base Stocks

Bob Duggal, ExxonMobil Technology & Engineering Company, Spring, TX

ExxonMobil has previously announced the introduction of a unique high-viscosity Group II clear and bright base stock – EHC 340 MAX™ – at a large scale, scheduled for startup in 2025. EHC 340 MAX™ will be available globally. EHC 340 MAX™ complements the viscosity range of the existing EHC™ slate with a base stock that is comparable in viscosity to Group I bright stock but allows customers to blend a wide range of high viscosity finished lubricants where traditional Group I base stocks use is limited. The new product is suitable for lubricants that require extra high viscosity, low temperature performance, high oxidation stability, high viscosity index, and a high flashpoint, which is critical for high temperature applications. Intended applications include gas engine oils, marine lubricants, greases, engine oils, industrial oils, and gear oils. In this discussion, we will review the application breadth and performance benefits of this innovative product in key lubricant applications.

4:30 pm – 5:00 pm

3908135: IMCD – A Sustainable Solution for an Evolving World – Esters as Base Oils and Components to Design a More Innovative Future

Vincenzo Aruta, John O'Keefe, IMCD GROUP, Milan, Italy

In the changing world of lubrication, the word "innovation" is closely linked to the environment. When it comes to defining sustainable lubricants, there is no simple, global definition or standard; the terms "bio," "sustainable" and "renewable" are used interchangeably, even though they have different and sometimes interconnected meanings. The ability to design extremely versatile but sustainable molecules is now synonymous with innovation. The ester family has a key role to play, both as base oils and components. Natural esters or triglycerides offer good lubricity, excellent viscosity index, and beneficial environmental and sustainable aspects. Synthetic esters, in contrast, offer higher oxidative and hydrolytic stability and other positive attributes. The choice of ester is important, with the levels of double-bond saturation offering different performance aspects to support the desired result. IMCD explains the options available when considering the use of esters in your lubricant formulation.

5:00 pm – 5:30 pm

3910814: OQ Chemicals – Synergistic Effects of a Blend of Polyalphaolefin and Polyol Ester for Potential High-Performance Lubricants in Electric Vehicles

Kyle Gross, OQ Chemicals Corporation, Bay City, TX

A blend of Synfluid® Polyalphaolefin 2 cSt (PAO-2) and Oxlube® L7-NPG shows beneficial effects for a future driveline lubricant application in electric vehicles (EVs). The addition of Polyol Esters (POEs) to PAOs shows an improvement in thermal and dielectric properties. These blends provide synergistic effects on properties like flash point, pour point, and kinematic viscosity resulting in greater low and high temperature performance. Additionally, the 80/20 PAO/POE blend displays better thermal properties versus PAO-2, with a potential for efficient cooling of electric motors. Furthermore, the dielectric properties of this blend are advantageous for electric vehicles, showing a higher breakdown voltage in comparison to PAO-2. Overall, the 80/20 PAO/POE blend offers a range of benefits for use in EVs, in addition to its well-known additive solubility, lubricity and seal compatibility, making it a promising solution for the next generation of high-performance e-driveline fluids.

5:30 pm – 6:00 pm

3905306: Richful Lube Additive Company Development Progress by 2022

Yida Tao, Richful Lube Additive, Xinxiang, Henan, China

Richful entered the lubricant additive industry in 2003 by commercializing a calcium alkyl phenol sulfonate detergent with remarkable performance. In the following years, Richful had enriched their product portfolio by making several key components. From the early 2010s, Richful put in the effort to develop DI packages demanded by the market. For the last decade, several mature DI products have been launched because of continuous investing in DI formulation researching and running qualification programs through worldwide anthropized test institutions. At the same time, Richful has been recognized by the global market with their service and reliable supply despite the global logistic constraints in recent years.

Session 2I | 104A

Electric Vehicles II

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

Session Vice Chair: Hyeok Hahn, Chevron Lubricants, Richmond, CA

1:30 pm – 2:00 pm

3833969: Various Copper Corrosion Test Methods for Electric Drivetrain Fluid Evaluations

Yungwan Kwak, Christopher Cleveland, Afton Chemical Corporation, Richmond, VA

Many OEMs have accelerated vehicle electrification in recent years to meet global regulations on pollutants, greenhouse emissions, and to increase fuel economy. A key component of the electric drive unit is an electric motor constructed with a significant amount of magnet wire. Copper metals can also be found in various other parts, such as (but not limited to); solenoids, printed circuit boards (PCBs), solder materials, and connectors. Poor protection against copper corrosion could lead to a failure with the motor and/or power electronics. Therefore, it's critical for a fluid to provide corrosion protection. This presentation discusses various copper corrosion tests for EV fluid evaluation. This includes 1.)

brief introduction of ASTM D130 copper corrosion test and its variations, 2.) copper wire corrosion test with PCB, 3.) copper corrosion test with PCB under electrification, 4.) stacked PCB test for conductive deposit tests, 5.) varnish coated copper corrosion test, and more.

2:00 pm – 2:30 pm

3808209: Next-Generation Tribology Component Technologies for E-Fluids

Christelle Chretien, Solvay, Bristol, PA

E-driveline units are mechanically less complex than traditional transmissions. However, they run under harsher conditions: higher speed, torque, higher temperatures, presence of electricity and new materials. Based on these new requirements, the core formulation of an E-fluid should be constituted of a robust tribology system made of anti-wear/extreme pressure agents and friction modifiers. This presentation will show how developmental tribology additives can bring solutions to these new EV requirements.

2:30 pm – 3:00 pm

3823603: Technologies for Improving the Performance of E-axle Fluids

Mari Iino, Shigeki Matsui, Shingo Matsuki, Akira Tada, Toshitaka Nakamura, ENEOS Corporation, Yokohama, Kanagawa, Japan

The lubricating performance of reduction gears and the cooling performance of motors are required for E-axle fluids. Here, low viscosity is effective for improving gear efficiency and motor cooling performance. However, extreme low viscosity leads to deterioration of fatigue life of the bearings and anti-seizure performance of the gears. Reducing the traction coefficient is effective to improve fatigue life. We examined a high-performance base oil with a low traction coefficient. Extreme pressure agents (EPs) are essential for anti-seizure performance, but they deteriorate insulation performance. The development of EPs with high anti-seizure performance while maintaining insulation was carried out. By applying a high-performance base oil and developed EPs, highly effective gear durability and deterioration prevention were confirmed on EV units and an electric vehicle (EV) test. A significant improvement on an E-axle efficiency test and an EV electric consumption test were also observed.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3835030: Performance Characteristics of Some EV Drivetrain Lubricants Under Electrified Condition

Ali Erdemir, Pushkar Deshpande, Leonardo Farfan-Cabrera, Seungjoo Lee, Texas A&M University, College Station, TX; William Anderson, Yungwan Kwak, Afton Chemical Corporation, Richmond, VA

Despite intensified efforts, there remain many challenges with respect to the lubrication performance of new electro-fluids (e-fluids) for use in future electric vehicles. Here, we compare the friction and wear performance of some e-fluids under electrified test conditions. Using surface and structure analytical techniques, we determine significant differences in the physical and chemical nature of the boundary films that formed under electrified test conditions. Specifically, boundary films formed under electrified conditions consisted primarily of harder forms of iron oxides which triggered severe abrasive wear. In some cases, the level of oxidation was not as severe and hence these e-fluids were able to provide better protection against wear. It looks that in EV drivetrains, electrical and tribological issues are intertwined in a very complex manner and hence the future fluid solutions must keep in mind not only the tribological but also the electrical realities of these vehicles.

4:30 pm – 5:00 pm

3839909: Comparison of Electric Drive Unit Lubricant Aeration Under High Speed Operation

Cole Frazier, Nolan Erickson, Cole Hudson, Southwest Research Institute, San Antonio, TX

Compared to internal combustion engines, motors used in electric vehicles typically spin at much higher speeds. Electric drive lubricants must perform in these high-speed environments – protecting gear interfaces and cooling components. The degree to which air is entrained in lubricant as it functions around rotating components at 15,000+ RPM is currently not well quantified. Air entrainment in the lubricant can cause poor heat transfer and reduce wear protection, which highlights the importance of measuring aeration in a representative way. At STLE's 2022 conference, SwRI presented aeration data collected on a drive unit with a 2-stage architecture. To further this effort to other drive units, SwRI repeated the experiment on a new drive unit with different speed characteristics, but similar two-stage gear architecture. In this presentation, SwRI will present how aeration results collected under the same test methodology compare for different drive units with similar architecture.

5:00 pm – 5:30 pm

3854042: Electrically Conductive Nanoparticle Additives for Greases Used in Electric Vehicles and Other Applications

Robert Jackson, Samuel Bond, German Mills, Auburn University, Auburn, AL

Electrified mechanical contacts and electrical connectors are an integral part of electric vehicles, and their reliable performance is essential. This has become increasingly important for electric vehicles where leakage current could potentially load the motor bearings and many other contacts in the drive system. It has been shown that this current can rapidly accelerate surface degradation via small scale arcing across lubricating films. Recent work suggests that metallic nanoparticle additives in lubricants could be used to improve the performance of these contacts. This work investigates silver nanoparticle enhanced greases under electro-tribological loads and in comparison to base and fully-formulated oils. The results suggest that the nanoparticles do enhance performance by reducing pitting from arcing, although oils with other additives also appear to have an enhanced performance.

5:30 pm – 6:00 pm

3810965: Sustainable E-Fluid Concepts for Electric Motor Cooling and Gearbox Lubrication

Christopher Dobrowolski, Shell Global Solutions, Hamburg, Germany

With the automotive world looking to quickly electrify, lubricant manufacturers are designing fluids that can best protect those highly integrated electric powertrains. E-motor friendly and efficient lubricant solutions are lower in sulfur and have lower viscosity. The next challenge is to provide lower CO_2 intensive products to decarbonize not only emissions but also the actual components used for producing and running cars, like the lubricant. In order to balance the technical properties and requirements with available and more sustainable components and base oils, Shell has generated a study to assess key aspects of those next generation formulations for transmission fluids. The study aims to generate and assess data for understanding performance aspects like efficiency and the potential to formulate low viscous fluid solutions, oxidation stability, material compatibility and CO_2 footprint.

Session 2K | 201A

Metalworking Fluids II

Session Chair: Jill Myers, The Timken Company, North Canton, OH

Session Vice Chair: Jeffrey Mackey, Advanced Chemical Concepts, Inc., Carmel, IN

1:30 pm – 2:00 pm

3802879: ASTM Standards Addressing Metalworking Fluid Health and Safety Issues

Frederick Passman, Biodeterioration Control Associates, Inc., Princeton, NJ

ASTM Subcommittee E34.50 on Standards addressing metalworking fluid health and safety issues was Chartered in 1992. The subcommittee's initial focus was to provide usable guidance that would help metalworking fluid end-users to reduce health risks associated with inhalation, skin-contact, or ingestion exposures. Over the course of the past 30 years, E34.0 has developed fourteen new standards and has two more in progress. The subcommittee's standards address metalworking fluid exposure control, test protocols for microbiological contaminants, and guides for testing metalworking fluid properties not related to performance. This presentation will provide an overview of E34.50's standards and their relevance to industry stakeholders.

2:00 pm – 2:30 pm

3809305: The Study of Novel Calcium Overbased Sulfonates Used for Rust Preventives

James Jianjun Wei, Wayne Mackwood, LANXESS, Toronto, Ontario, Canada

Historically barium sulfonate based rust preventives have been considered superior alkali metal sulfonates for corrosion inhibition. However, with the increasingly stringent government regulations for environmental and health protection, the use of barium sulfonates has been significantly decreased due to the toxic nature of barium and high cost of its waste disposal. In this work, we have examined the use of calcium sulfonates, and in particular their soap composition as well as the optimum TBN/Soap ratio needed to achieve excellent corrosion inhibition. The focus was on the potential replacement for the industry standard 70 TBN overbased barium sulfonate, but comparisons were also made with neutral Ba sulfonate. Several standard corrosion test methods were used to evaluate and compare their performances. The test results demonstrate that different calcium sulfonate containing products can offer much better rust inhibition characteristics than a 70 TBN barium sulfonate.

2:30 pm – 3:00 pm

3810790: Case Study of Monitor and Correction of Field Coolant Emulsions by Light Scattering Instrument and Good Correction Method

Yixing Philip Zhao, Quaker Houghton, Conshohocken, PA

An important aspect of the sustainability for soluble metalworking fluids is sump longevity. Our formulators put a lot of affords to develop robust MWF products with good lubricity, excellent emulsion stability, good biostability, environmentally friendly and good resistance to various contaminations such as tramp oils. However, if people do not maintain MWF in the field, any good product can go bad. Fouled fluids cause health/safety issues and productivity loss due to coolant separation by tramp oils or other contaminations. This paper presents a case study of monitoring field coolant stability by a light scattering instrument which detects small oil droplet changes and predicts emulsion stability much earlier than our eyesight and other traditional test methods. The talk will focus on the monitor of tramp oil effects on emulsion stability. This method helped greatly, along with a good correction process, a recovery process with a fouled coolant fluid due to tramp oil in a large sump.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3810961: Extreme Pressure Sulfurized Additives for Metalworking Fluid Ester-Based Formulation

Guillaume Notheaux, SEQENS, Porcheville, France

Sustainability is becoming a key factor to consider when developing a lubricant. Thus, metalworking fluid formulators are looking for alternative base oils to meet environmental and performance requirements especially for extreme pressure additives. Using esters as base oils helps to face this new challenge, but the related consequence is often the copper corrosion performance. In this context, mastering the sulfurization process is the key parameter to fine tune the right extreme pressure sulfur additives. Distribution of the sulfur bridge length, concept of labile sulfur, impact on active sulfur and the thermogravimetric analysis curves, will be the tools exposed to propose an extreme pressure additive, sulfurized compounds and non-copper corrosive in an ester base oil.

4:30 pm – 5:00 pm

3811719: Sustainability Beyond Carbon Footprint

Michael Stapels, Kao Chemicals GmbH, Emmerich, Germany

Metalworking manufacturers and end-users face numerous new regulations and sustainability trends. While ideal performance and price competitiveness has been the golden standard of success for decades, additional factors such as the product carbon footprint and renewable carbon content are recent parameters to be considered. To get the holistic picture, it is important in pondering on one side the renewability, multifunctionality, efficiency and hazard level of additives and on the other side the performance, fluid longevity and hazard level of works of a fluid until its waste disposal and recycling. It is indispensable to study the complete metalworking fluid life cycle to ensure a responsible use of our resources. A reasonable, measurable, and comparable approach is desirable on our way towards improvement of sustainability in metalworking and in the prevention of misunderstood and misleading product positionings.

5:00 pm – 5:30 pm

3808450: Chlorine Use in Stainless Steel Tube Manufacturing

James Brooks, RichardsApex Inc., Philadelphia, PA

Stainless steel tubing is critical for nuclear, medical, aerospace, military, and countless other applications. These high strength alloy tubes are nearly universally formed using chlorinated lubricants. Therefore, when regulatory agencies increase pressure on the use of chlorinated paraffin, the stainless-steel tube industry bears a significant burden. This presentation attempts to provide an impartial explanation for the purpose of chlorine in the stainless-steel tube industry, a legitimate strategy for phasing it out, and the consequences of those actions.

5:30 pm – 6:00 pm

3833657: Analysis of the Tool Margin-Wall Contact During MQL Deep-Hole Drilling of AISI 4140 Steel Through a Surface Integrity Study

Peter Neal, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Many automotive manufacturers have adopted Minimum Quantity Lubrication (MQL) to reduce the environmental impact and cost of their machining operations. There is limited understanding of the influence of

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this lubrication type on the quality of the machined surface, particularly with regards to high strength materials. In this study, MQL and flood coolant methods are compared in high speed deep-hole drilling of AISI 4140 martensitic steel using optimized double-margin tooling. A regression model is generated for cutting forces and surface roughness and microstructural evolution is examined through application of XRD and EBSD techniques. High temperature compression testing is also conducted to characterize the change in flow behavior of the material with temperature and strain. It is proposed that the tool margin-wall contact is a key contributor to surface integrity and warrants further investigation.

Session 2M | 202A

Herbert S. Cheng Memorial Symposium

Challenges in Lubrication and Tribology Modeling II

Session Chair: Q. Jane Wang, Northwestern University, Evanston, IL

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3887538: Frontiers of Surface Engineering and ribology for a Green and Sustainable Future

Ali Erdemir, Texas A&M University, College Station, TX

Friction and wear collectively consume nearly a quarter of the world's energy output and causes more than 8 gigatons of CO_2 emissions annually. With increasing mobility and industrial activities, there is no doubt that adverse impact of friction and wear on energy and environment will continue to intensify in coming years. Accordingly, there is an urgent need for more efficient, green, and long-lasting tribological solutions that can help reverse such an unsustainable trend. In recent years, great strides have been made in the design of new materials and surface engineering technologies that can literally vanish friction and wear. In this presentation, a comprehensive overview of recent advances in friction and wear control technologies is provided especially within the framework of advanced functional coatings. Special emphasis is placed on those discoveries that can save energy, improve durability, and thus protect the environment for a sustainable future.

2:00 pm – 2:30 pm

3857547: Fluid/Solid Interactions in Lubrication – Recent Developments and Future Perspectives

Daniele Dini, Imperial College London, London, United Kingdom

Fluid-solid interactions are ubiquitous in lubricated systems and control the majority of the processes in tribological contacts. Recent advances in computational methods and resources have fueled numerical studies to explore novel techniques for solving a plethora of problems involving lubrication across the scales with increased degree of sophistication. Applications vary from the solution of automotive systems to soft tissue lubrication, biomedical devices, triboelectric nanogenerators etc. The present contribution provides an overview of the recent methodological advances, some inspired by the work of Prof. Herbert Cheng, to tackle a multitude of complex lubrication problems. Various cases are presented and compared to results generated by other existing solvers and other experimental data to validate the proposed frameworks. The talk will conclude with a perspective that looks at the outstanding issues in this field and proposes a way forward to tackle at least some of them.

2:30 pm – 3:00 pm

3833491: Unsteady Multiscale Simulation of Lubricated Rough Surfaces

Noel Brunetiere, Arthur Francisco, Institut Pprime, Futuroscope Chasseneuil Cedex, France

When dealing with lubrication of rough surfaces, averaging methods such as homogenization or flow factors suffer from a lack of accuracy when the surfaces are nominally parallel while deterministic approaches are limited to the simulation of small areas. It is now known that multiscale methods can overcome both limitations. A fine mesh named bottom scale mesh is used to obtain an accurate pressure distribution. To reduce computation burden, this mesh is split in several sub-domains connected through a top scale mesh ensuring global mass conservation. In many lubrication problems, the situation is transient, and it is important to extent these multiscale methods to time-varying problem. In this work, the development of a transient multiscale approach is presented. Several examples of application such as squeeze problems and lubrication of two rough surfaces are presented.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3833864: Explicit Flow-Continuity-Enforced Elastohydrodynamic Lubrication Analyses with a Mass Conservation Algorithm

Shuangbiao Liu, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Starvation may occur in a lubricated interface globally and locally around asperities, and cavitation may appear around divergent spaces at different scales. Various modified Reynolds equations with mass conservation algorithms have been developed to deal with starvation/cavitation. However, numerical flow-continuity examinations have been neglected in most lubrication analyses, and actual levels of flow-continuity of numerical solutions have not been demonstrated. This work explicitly evaluates flow values, along the velocity direction, passing a single mesh width as well as the total width of a computation domain. This work reveals the importance of low-pressure regions (dimensionless pressure < 1%) to flow continuity, and film-reformation boundaries of starvation/cavitation zones. Hybrid relaxation factors are utilized with the unity assigned to the low-pressure regions. This numerical solver is further applied to study the lubrication of dimpled surfaces.

4:30 pm – 5:00 pm

3854905: Strength from Weakness: Dynamicity in Biotribological Interfaces

W. Gregory Sawyer, Research Institute of Industrial Science and Technology, Gainesville, FL

Dynamic hydrogel networks are a central feature of biological systems – soft, living, active matter. For example, wet epithelial surfaces form the largest interface in biological systems and are protected by the continuous production and maintenance a functionally graded dynamic aqueous gel, mucous. These gels are formed from a wide array of heavily glycosylated proteins (mucins and glycoproteins) and use "flickering" supramolecular and dynamic-covalent intermolecular interactions as crosslinkers. Mucous is responsible for key cell-protective and barrier functions including hydration, lubrication, and solid contaminant removal.

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5:00 pm – 5:30 pm

3854202: Lubricant-Chemistry Kinetic Model of Boundary Lubrication by Oil Additives Using SOL, QM+MD, and Machine Learning

Zhijiang (Justin) Ye, Miami University, Oxford, OH; Chao Zhang, Shanghai University, Shanghai, China

Structure oriented lumping approach organizes a set of certain of structural features or groups for any tribochemical molecule. Based on the molecular lump of participating materials and reaction rules, the boundary lubrication model can describe the processes of complex tribochemical reaction on molecular level and predict antiwear film formation and removal. Both hybrid quantum chemical molecular dynamics simulations and experiments are conducted to generate high-throughput synthetic data for machine learning training, validation, testing and prediction. QM Materials Studio DMol3software, MD LAMMPS with ReaxFF force field, and deep learning are exploited to understand the causality between the microstructural features and the multiscale properties. Application of all rules to all components of the mixture by using each reaction rule as the outer loop and each structure vector group as the inner loop generates the entire reaction network representing the chemistry of the process.

Session 2N | 202B

Nanotribology II

Session Chair: Mehmet Baykara, University of California, Merced, Merced, CA

Session Vice Chair: TBD

1:30 pm – 2:30 pm

3847661: Invited Talk – The Nucleation, Growth, and Adhesion of Water Bridges in Sliding Nano-Contacts

Bart Weber, Felix Cassin, Rachid Hahury, Thibault Lancon, Steve Franklin, Advanced Research Center for Nanolithography, Amsterdam, Netherlands

We provide experimental observations of the nucleation and growth of water capillary bridges in nanometer gaps between a laterally moving Atomic Force Microscope (AFM) probe and a smooth silicon wafer. We find rising nucleation rates with increasing lateral velocity and a smaller separation gap. The interplay between nucleation rate and lateral velocity is attributed to the entrainment of water molecules into the gap by the combination of lateral motion and collisions of the water molecules with the surfaces of the interface. The capillary volume of the full-grown water bridge increases with distance between the two surfaces and can be limited by lateral shearing at high velocities. Our experimental results demonstrate a novel method to study in situ how water diffusion and transport impacts dynamic interfaces in the nanoscale, ultimately leading to friction and adhesion forces at the macroscale.

2:30 pm – 3:00 pm

3831137: Molecular Dynamics Investigation of the Friction Mechanism in a Humid Nanocontact

Igor Stankovic, Institute of Physics Belgrade, Zemun, Belgrade, Serbia; Olivier Noel, Le Mans Universite, Le Mans, France; Pierre-Emmanuel Mazeran, Sorbonne Universites, Universite de Technologie de Compiegne, Compiegne, France

Water molecules' role in the friction behavior mechanism of a hydrophobic and hydrophilic nanocontact is still poorly understood. It is commonly accepted that the water molecules are squeezed out of the contact of hydrophobic surfaces or pulled between hydrophilic surfaces. We demonstrate that an intuitive paradigm needs to be refined using circular mode atomic force microscopy [1,2] experiments coupled with molecular dynamics simulations. As a result, we present a new mechanism considering a capillary bridge produced within the sliding nanocontact by the accumulation of water adsorbed on the substrate [3]. Then we show how a full slip regime of the capillary bridge sliding on the substrate perfectly explains the observed tribological behaviors.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3832988: Using Friction Hysteresis of 2D Materials to Uncover Properties of the Substrate

Philip Egberts, Chaochen Xu, University of Calgary, Calgary, Alberta, Canada; Zhijiang (Justin) Ye, Miami University, Oxford, OH

Two-dimensional (2D) materials exhibit physical properties that promise to significantly improve both dry and oil-based lubricants. While many studies have shown the impact of 2D materials on reducing friction, a model that describes the factors affecting their lubricating properties has not yet been developed. Here, we re-examine two factors, including substrate adhesion and water intercalation, and observe their impact with atomic force microscopy experiments on the stiffness of the 2D material and its lubrication properties to better link friction with physical parameters of the lubricant and substrate. Further, mechanistic insight into the sliding contact was developed using molecular dynamics simulations that replicated the experimental measurements. In these simulations, the substrate energy, surface roughness, and intercalated water showed to significantly impact the contact area of the sliding interface between an asperity and the 2D material.

4:30 pm – 5:00 pm

3833606: MXene Nanosheets Exhibiting Layer-Dependent Friction Properties

Eui-Sung Yoon, Prashant Pendyala, Seon Joon Kim, Korea Institute of Science and Technology, Seoul, Republic of Korea

MXenes are a new class of 2D solid-state-friction materials with atomically thin multi-layered structures. The layers of MXenes were shown to exhibit large inter-layer binding due to the presence of a large number of functional groups. How such large inter-layer binding affects the nanoscale friction was not understood. We experimentally investigated the nanoscale frictional properties of layers of MXene nanosheets using friction force microscopy. We showed that the friction of MXenes reduced as the number of layers increased. Using the puckering mechanism of friction, we showed that out-of-plane mechanical properties of MXene layers primarily influence the nanoscale friction behavior of MXenes. Furthermore, contrary to the prevalent understanding, we showed that higher inter-layer binding in MXenes helps the layer-dependent behavior enhancing the overall frictional performance. Our study critically enables further exploration of MXenes as nanoscale solid-state lubricants.

5:00 pm – 5:30 pm

3813225: Nanoscale Friction of High Entropy Alloy Sulfide Thin Films in Comparison with Molybdenum Disulfide

Gokay Adabasi, Joshua Ancheta, Emmanuel Maldonado, Mehmet Ozdogan, Mehmet Baykara, University of California, Merced, Merced, CA; Aditya Deshpande, Koichi Tanaka, University of California, Los Angeles, Los Angeles, CA; Suneel Kodambaka, Virginia Tech, Blacksburg, VA

The outstanding wear and corrosion resistance exhibited by high entropy alloys (HEA) make them ideal candidates for coatings in mechanical systems. On the other hand, the question of whether HEA thin films will also act as solid lubricants remains open. Here, we perform

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nanoscale friction measurements on HEA-sulfide ((VNbTaMoW)S_2) thin films via AFM. Results reveal 1.) the influence of deposition time on film morphology and 2.) the presence of isolated areas of low friction on film surfaces. We compare the friction results on (HEA)S2 thin films with those on sputter-deposited molybdenum disulfide (MoS_2) and find that they are on the same order. Finally, variable temperature X-ray diffraction (XRD), performed up to 800°C, reveals that (HEA)S2 films exhibit improved oxidation resistance when compared with MoS_2 films. Combined, the results show that (HEA)S_2 thin films exhibit remarkable potential as environmentally-resistant solid lubricant coatings.

Session 2O | 202C

AI and Machine Learning II

Session Chair: Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

Session Vice Chair: Prathima Nalam, University at Buffalo, Buffalo, NY

1:30 pm – 2:00 pm

3833889: A New Perspective on Tribological Data via Advanced Statistics and Artificial Intelligence

Nicole Doerr, Georg Vorlaufer, Josef Prost, AC2T research GmbH, Wiener Neustadt, Austria

Recent developments in data science, in particular methods from machine learning (ML) and artificial intelligence (AI), promise new opportunities in gaining detailed knowledge about processes, e.g., operation of machines. In combination with large data sets ("big data"), computers can be trained to classify the current health status of machine elements, e.g., bearings, gears, and predict the remaining useful life based on on-line sensor data. At AC2T research GmbH, methods of data science are used to, e.g., identify friction regimes in tribometer experiments, correlate chemical information from different lubricants, or detect changes in the wear behavior of test specimen. Therefore, data is usually generated by on-line sensors or by ex-post analytical devices such as FTIR spectrometer. Some recent examples from our institute including the classification of operating conditions of self-lubricating bearings and the correlation of oil degradation and wear behavior are discussed.

2:00 pm – 2:30 pm

3833776: Chemometric and FTIR Spectroscopy for Determination of Physicochemical Properties of Engine Oil

Ganesh Natrajan, Sara Rezaee, Aparna Bala, Ramaratnam Visweswaran, Viswa Group, Houston, TX

Lubrication oil is particularly important to maintain the optimum performance and reliability of a combustion engine. Currently, routine tests are carried out using ASTM procedures, which can be time-consuming and require a large amount of lubricant sample and solvent. Chemometrics offers a wide range of multivariate analysis methods that enable a more thorough use of test data. In this study, Fourier-transformed infrared spectroscopy together with prediction models such as partial least square (PLS) and PLS-DA (discriminant analysis) helped to create a model for the prediction of Total Base Number (TBN) and chemical composition (Paraffin, Naphthene, and Aromatic (PNA) content) of the engine oil samples for oils with a viscosity range between 70-150 cSt. A strong correlation between values of TBN by the FTIR-PLS model and ASTM D2896 was determined. Also, the correlation between PNA content predicted by FTIR – PLS method and ASTM D3238 was acceptable.

2:30 pm – 3:00 pm

3831643: Digital Advancements in Tribofilm Analysis

Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX; Sanket Deshmukh, Rishu Saxena, Shell India Markets Pvt Ltd., Bangalore, India; Grace Uche, Shell Information Technology International Inc., Houston, TX; Gary Pollock, Altin Veliu, Shell Global Solutions (UK), London, United Kingdom

One of the key functions of a lubricant is to form a protective film that reduces friction and wear between moving parts. This protective film is called the tribofilm. Mini traction machine is an experimental setup which enables acquisition of tribofilm images in-situ. By analyzing these tribofilm images, valuable information and statistics regarding the film thickness and uniformity can be extracted, thereby determining the protective capability of a lubricant. Currently, tribofilm image analysis is a manual workflow which can be a subjective and time-consuming process. Our presentation will feature in-depth explanation on how we digitally automated the tribofilm image analysis workflow to extract objective metrics of lubricant tribofilm/friction performance. We further highlight the use of AI/ML algorithms to assist lubricant innovation and product development.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3840701: Using Machine Learning Algorithms to Relate the Surface Topography of As-Built Surfaces to Additive Manufacturing Process Parameters

Bart Raeymaekers, Virginia Tech, Blacksburg, VA

Metal additive manufacturing (AM) enables rapid fabrication of structural parts with complex geometry. Recent research demonstrates the importance of the relationship between the surface topography of metal AM parts and its mechanical properties because surface defects and porosity relate to the fatigue life of the part. Furthermore, costly post-processing of as-built AM surfaces drives the need to manufacture tailored as-built surface topography. In this presentation, we discuss deriving data-driven models from surface topography data and laser-powder bed fusion (L-PBF) process parameters using machine learning (ML) algorithms. We quantify the prediction accuracy of models derived from different ML algorithms and show that decision tree and artificial neural network algorithms result in the highest prediction accuracy. This research is relevant to transitioning metal AM from rapid prototyping to producing functional end-use parts, by reducing the need for costly post-processing.

4:30 pm – 5:00 pm

3834513: How to Get to Big Data in Tribology? A Hands-on Example

Nikolay Garabedian, Ilia Bagov, Christian Greiner, Karlsruhe Institute of Technology, Karlsruhe, Germany

Applying machine learning and active research data management in tribology have been slower to adopt than in other scientific communities. Arguably, the main hurdle is also what makes tribology a distinctly exciting field – its extreme multidisciplinarity. Public funding agencies have been clear in their policy commitments: scientists need to treat data as a valuable societal resource and not just as a path to a publication. Industrial R&D departments have also realized the long-term value of "good data". In this presentation, we will exemplify the specific framework of solutions which our group has been developing for over 3 years. The two core principles fundamental to the framework are community engagement and FAIR data (Findable, Accessible, Interoperable, Reusable). With this framework we aim to link tribological results to other already digitalized domains so that we can apply scalable artificial intelligence techniques for better-controlled friction, wear, and lubrication systems.

5:00 pm – 6:00 pm | Panel Discussion

Overview

Download the STLE Mobile App for the most up-to-date schedule. (pg. 15)

Tuesday, May 23

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Commercial Exhibits and Student Posters
9:30 am – 12:00 pm & 2:00 pm – 5:30 pm – **Hall B**

Refreshment Break
10:00 am – 10:30 am – Hall B

Technical Sessions (8:00 am – 12:00 pm)

- 3A • Lubrication Fundamentals III: Friction Modifiers – **101A**
- 3B • Rolling Element Bearings III – **101B**
- 3C • Fluid Film Bearings I – **102A**
- 3D • Materials Tribology III – **102B**
- 3E • Condition Monitoring III – **102C**
- 3F • Environmentally Friendly Fluids II – **103A**
- 3G • Gears I – **103B**
- 3H • Commercial Marketing Forum III – **103C**
- 3I • Electric Vehicles III – **104A**
- 3K • Metalworking Fluids III – **201A**
- 3N • Nanotribology III – **202B**

President's Luncheon/Business Meeting
12:00 pm – 2:00 pm – **Grand Ballroom**

Technical Sessions (2:00 pm – 6:00 pm)

- 4A • Lubrication Fundamentals IV: Polymers – **101A**
- 4B • Rolling Element Bearings IV – **101B**
- 4C • Fluid Film Bearings II – **102A**
- 4D • Materials Tribology IV – **102B**
- 4F • Environmentally Friendly Fluids III – **103A**
- 4G • Gears II – **103B**
- 4H • Commercial Marketing Forum IV – **103C**
- 4I • Electric Vehicles IV – **104A**
- 4K • Metalworking Fluids IV – **201A**
- 4L • Tribochemistry I – **201B**
- 4N • Nanotribology IV – **202B**

Exhibitor Appreciation Break
3:00 pm – 4:00 pm – **Hall B**

Ideation Event: Roundtable Discussions
4:00 pm – 6:00 pm – **Grand Ballroom 1/3**

Exhibition hours

- **Tuesday, May 23**
  (9:30 am – 12:00 pm) & (2:00 pm – 5:30 pm)
- **Exhibitor Appreciation Hour** (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win.
  (Booth #205)

TIME	SESSION 3A Lubrication Fundamentals III Room 101A	SESSION 3B Rolling Element Bearings III Room 101B	SESSION 3C Fluid Film Bearing I Room 102A
8:00 am – 8:30 am	Friction Reduction Performance of Nanodiamonds in Presence of Organic Friction Modifier, A. Khan Piya, p.70	Influence of Residual Stresses Due to Cold Forming on Stainless Steel Bearings, A. Bodewig, p. 72	An Optimized Normalization of the Inlet Computation Zone for Isothermal EHL Contacts, Y. Higashitani, p. 73
8:30 am – 9:00 am	Research on the Activation and Performance Retention of Organomolybdenum Additives, B. Casey, p. 70	Influence of High Loads on the Fatigue Life Behavior of Rolling Bearings, S. Dechant, p. 72	Experimental Investigation on Thrust Bearing Cooling Arrangement Within Tilting Pads, F. Najar, p. 73
9:00 am – 9:30 am	Effect of Organic Friction Modifiers on Friction and Wear of HDDEO Formulations, A. Kurchan, p. 70	An Investigation into Rolling Contact Fatigue Performance of Aerospace Bearing Materials, S. Lorenz, p. 72	Static and Dynamic Behavior of a Porous Bearing Lubricated by Nanofluids, B. Bou-Saïd, p. 73
9:30 am –10:00 am	Study of the Interaction Between Esters and Different Friction Modifier Additives in a Group IV Base Stock, G. Cañellas, p. 70	Predicting Surface Pitting Fatigue Behavior Using Torsion Fatigue Characteristics, K. Singh, p. 72	Dynamic Analysis of Finite Porous Journal Bearing Considering Cavitation, E. Clifford, p. 74
10:00 am – 10:30 am	**Break**	**Break**	**Break**
10:30 am – 11:00 am	Bench Friction Evolution of Engine-Aged Oils, B. Miller, p. 70	Effect of Surface Roughness & Lubrication Regime on Bearing RCF Life Using Computational Modeling Tool, B. Jalalahmadi, p. 73	Thin Film Momentum and Energy "Bulk Flow" Equations with Velocity and Temperature Profiles, M. Arghir, p. 74
11:00 am – 11:30 am	Measuring the Frictional Behavior of Lubricants with an Antiwear Additive and Different Friction Modifiers, K. Tomlinson, p. 70	Wear Induced Changes in Surface Topography During Running-in of Rolling-sliding Contacts, M. Sai Dhiraj Sakhamuri, p. 73	Invited Talk – Fundamentals of Fluid Film Bearings Used in Turbomachinery Operated at Extreme Conditions, K. Ryu, p. 74
11:30 am – 12:00 pm	Scaling of Friction Behavior in the Mixed Lubrication Regime through a Modified Hersey Number, E. Hansen, p. 72	Investigation on Strength of Steel and Silicon Nitride Rollers Against Fracture, N. Londhe, p. 73	
	SESSION 4A **Lubrication Fundamentals IV: Polymers** **Room 101A**	**SESSION 4B** **Rolling Element Bearings IV** **Room 101B**	**SESSION 4C** **Fluid Film Bearings II** **Room 102A**
2:00 pm – 2:30 pm	Same Engine, Less CO_2 – Lubricant Solutions to Maximize Fuel Economy without Compromising Oil Consumption, S. Michael, p. 86	Atomistic Investigation of White Etching Bands Transformations in Rolling Element Bearings, M. El Laithy, p. 88	Nonlinear Dynamics of an Accelerating Rotor Supported on Self-Acting Air Journal Bearings, M. Pattnayak, p. 90
2:30 pm – 3:00 pm	Dual Functional Additives: Polymer Adsorption and Boundary Effects, A. Mohamed, p. 88	Initiation and Drivers of Butterfly and White Etching Area Manifestation In Bearing Steels, M. El Laithy, p. 89	Observation of Polymer Chain Deformation in Oil Under High Shear, T. Kusumoto, p. 90
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Low Temperature Viscometrics and PPD Effect on Group III Base Oils, J. Scherger, p. 88	Thermal Simulation of Bearing Components in Customer Applications, T. Shive, p. 89	On the Experimental Performance of Additively Manufactured Hybrid Fluid Film Bearings, K. Ryu, p. 90
4:30 pm – 5:00 pm	Viscoelasticity of Lubricants with Polymer Additives Sheared in Nanogaps and Their Temperature Dependence, S. Itoh, p. 88	Comparison of Thermal Characteristics of an Aero-Engine Cylindrical Roller Bearings: All-Steel Versus Hybrid, R. Kerrouche, p. 89	Multi-Objective Taguchi-Grey Relational Analysis of Bearing Parameters on the Steady-State Performance of Three-Lobe Journal Bearing …, A. Ambekar, p. 90
5:00 pm – 5:30 pm	Effect of Polarity of Polymer Additives on Their Adsorption and Boundary Film Formation, Y. Song, p. 88	Simulation of Temperature Distribution in Rolling Bearings, H. Grillenberger, p. 89	A Directed-Lubrication Thrust Bearing Solution for High-Speed and/or High-Load Applications, B. Fabijonas, p. 90
5:30 pm – 6:00 pm	Lubrication Fundamentals Business Meeting	Investigation of Heat Generation in Ball Bearings for Liquid Rocket Engine Turbopumps, H. Kakudo, p. 89	Fluid Film Bearings Business Meeting
6:00 pm – 6:30 pm		Rolling Element Bearings Business Meeting	

SESSION 3D Materials Tribology III Room 102B	SESSION 3E Condition Monitoring III Room 102C	SESSION 3F Environmentally Friendly Fluids II Room 103A	
	Wear Metal Alarm Limits Versus Trending, E. Zabawski, p. 76	Renewable Base Oils for Sustainable Lubricants: A Transparent & Scientific Approach, W. Huybrechts, p. 77	**8:00 am – 8:30 am**
Dry Sliding Wear of Metal-Oxide Filled PTFE Composites, J. Swets, p. 74	Rapid Identification and Quantification of Ethylene and Propylene Glycol in Engine Coolant by Gas Chromatography, N. Lancaster, p. 76	Viscosity Modifiers with an Environmental Acceptable Design and an Improved Performance, M. Combarros, p. 77	**8:30 am – 9:00 am**
Qualitative Analysis of Transfer Film Properties on Wear Performance of Metal-Filled Fluoropolymer Composites, F. Haque, p. 74	Filter Element Construction and Electrostatic Discharge Polarity in Hydraulic Systems, J. Duchowski, p. 76	Degradation and Lubrication of Stern Tube Seals – Understanding Seal Durability, T. Briggs, p. 78	**9:00 am – 9:30 am**
Don't Worry, It Will Get Better: How (Particle) Break-Ups Improve Wear in PTFE Composites, M. Sidebottom, p. 74	An Automated Approach to Gravimetric Dilution for Lubricant ICP Sample Preparation and Analysis, S. Twining, p. 77	Achieving Performance and Sustainability Objectives with Ester Technologies, M. Hof, p. 78	**9:30 am –10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:30 am**
On the Dry Sliding Wear of PEEK-PTFE Composites, E. Anders, p. 76	Asset Condition Assessment – Field Application, M. Yarlott, p. 77	An Environmentally-Responsible Approach to Improving Your Heat Transfer Fluid Chemical Hygiene, R. Beemsterboer, p. 78	**10:30 am – 11:00 am**
Tribological Behavior of PTFE-PEEK: Influence of Composite Processing, K. Van Meter, p. 76	Real-Time Online Determination of Lubricant Remaining Useful Lifetime and Detection of Common Lubrication Contamination Events, T. Mack, p. 77	A New Safer and Sustainable Turbine Oil, G. Herve, p. 78	**11:00 am – 11:30 am**
Design of PEEK-Based Composites for Multifunctional Applications, S. Gupta, p. 76	The Impact of Oil Additive Types and Their Content on the Oil Electrical Conductivity, J. Duchowski, p. 77	Eco-Sustainable Synthetic Ester Oil Formulations for Micro-Electromechanical Systems: Tribological Investigations, N. Ponnekanti, p. 78	**11:30 am – 12:00 pm**
SESSION 4D **Materials Tribology IV** **Room 102B**		**SESSION 4F** **Environmentally Friendly Fluids III** **Room 103A**	
			2:00 pm – 2:30 pm
		Tribological Performance in High-Pressure Carbon Dioxide Environment for Compressor Application, A. Asif, p. 92	**2:30 pm – 3:00 pm**
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**3:00 pm – 4:00 pm**
Comparing the Performance of Molded Versus Machined High-Performance Plastics in Unlubricated Friction and Wear Environments, T. Alauzen, p. 92		Novel Green Friction Modifiers for Aqueous Lubricants, S. Davison, p. 92	**4:00 pm – 4:30 pm**
Tribological Study of Oil-lubricated Thick Polydopamine + Polytetrafluoroethylene + Cu Nanoparticle Coatings, S. Ghosh, p. 92		Investigating the Effect of Novel Processing Routes in Enhancing the Tribological Behavior of Soybean Oil, P. Bhowmik, p. 94	**4:30 pm – 5:00 pm**
Mechanistic Understanding of Substrate Roughness Effect & Coating Cohesion on the Scratch Resistance of Polytetrafluoroethylene-Based Thin Coatings, C. Miller, p. 92		Environmentally Friendly Fluids Business Meeting	**5:00 pm – 5:30 pm**
			5:30 pm – 6:00 pm

TUESDAY >>

TIME	SESSION 3G Gears I Room 103B	SESSION 3H Commercial Marketing Forum III Room 103C	SESSION 3I Electric Vehicles III Room 104A
8:00 am – 8:30 am	Pitting Detection in an Early Damage Stage for AI-Based Operating Strategies in Wind Power Drives, L. Merkle, p. 80	Oil Filtration Systems – Clean Oil is the Lifeblood of your Turbine System, T. Lisy, p. 81	High Temperature Lightweight Al-Alloys for EV Regenerative Brake Rotors, T. Grejtak, p. 82
8:30 am – 9:00 am	Formulating for an Increasingly Complex Industrial Gear Landscape, P. Norris, p. 80	Biosynthetic Technologies – Estolides – High Performance Sustainable Base Oils for Lubricant and Metalworking Formulations, M. Kriech, p. 81	High-Pressure Fuel Pump Performance with Low Lubricity Fuels Monitored with Acoustic Emission Technology, N. Murthy, p. 82
9:00 am – 9:30 am	Investigations on the Pitting Resistance and Efficiency of Gears with Very Smooth Surfaces, A. Sorg, p. 80	LANXESS – Sulfur Carrier EP Additive Portfolio – EP Additive Trends in MWF Formulations, H. Sudmeyer, p. 81	Impact of High Speed of Rolling Element Bearings in Oil Lubricated Contacts, F. Qureshi, p. 82
9:30 am –10:00 am	Method for Characterization of Wear Behavior of Steel-Bronze Rolling-Sliding Contacts Relating to Worm Gears, P. Schnetzer, p. 80	King Industries – Introducing KX460 – A High Performance Water-Based Rust Preventive Additive for Formulations Demanding Superior Metal Parts Protection in Severe Corrosion Conditions, C. Pratt, p. 81	A Novel Method of EV-Fluid Differentiation in Compatibility with Enameled-Insulated Copper Wires, A. Minz-Schuett, p. 82
10:00 am – 10:30 am	**Break**	**Break**	**Break**
10:30 am – 11:00 am	AI-Based Prognostic and Health Management in Wind Power Drives, L. Binanzer, p. 80	Eastman Synergex™ Multifunctional Amine Additives for Metalworking Fluids, R. Ash, p. 81	Multi-Physics and Multi-Scale Prediction of Tribological Behavior of Electric Powertrain, M. Mohammadpour, p. 84
11:00 am – 11:30 am	Catastrophic Failure of Gears in a Tube Mill, A. Cardenas, p. 80	Introducing Lubrizol's® EcoAssurant™ Industrial Environmentally Acceptable Lubricant (EAL) Portfolio Featuring the New IG22EL Series of Industrial Gear Fluids, J. Dickstein, p. 82	Performance Evaluation of Greases for Electric Vehicle Motors, G. Calderon Salmeron, p. 84
11:30 am – 12:00 pm	Development of an Industrial Gearbox Relevant Micropitting Test, M. Ingram, p. 81	Munzing – FOAM BAN® Defoamers for Tank Side use in Aqueous Metalworking Fluids, S. Velez, p. 82	Ultrasonic Measurement of Interference Pressures for a Planetary Gear Shaft-Bush Contact, G. Nicholas, p. 84
	SESSION 4G **Gears II** **Room 103B**	**SESSION 4H** **Commercial Marketing Forum IV** **Room 103C**	**SESSION 4I** **Electric Vehicles IV** **Room 104A**
2:00 pm – 2:30 pm	Industrial Gear Efficiency Demonstration, A.w Gant, p. 94	VBASE® Oil Company – Secondary Polyol Esters™ – Novel Sustainable Group V Base Oils, M. Greaves, p. 94	Oil Aeration: Findings for Testing in High Speed, Low Volume Systems, R. Hein, p. 95
2:30 pm – 3:00 pm	Performance Enhancement of Plastic Gears – The Potential of Laminated Woven-Carbon-Fiber Einforced Plastics, D. Zorko, p. 94	Evonik Oil Additives – Win with Efficiency and Formulation Flexibility – Lubricant Solutions to Maximize Fuel Economy without Compromising Oil Consumption, M. Hauschild, p. 94	Flammability and Combustibility of Oils in the Presence of High Voltages, P. Shiller, p. xx
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Gears Business Meeting	Kao Chemicals – Solutions for Today's Metalworking and Cleaning Formulations, S. Wohlfahrt, p. 95	Rheological Test Methods for E-Lubricants, C. Sanchez, p. 96
4:30 pm – 5:00 pm		ExxonMobil – Peak Performance, More Fuel Economy Savings with SpectrasSyn™ in the Automotive Lubricant Space, M. Patel, p. 95	Test Development for Copper Corrosion in E-Fluids, G. Philibert, p. 96
5:00 pm – 5:30 pm		BASF Corporation – New Offerings and Developments in BASF Lubricant Antioxidant Technology, K. DeSantis, p. 95	Monitoring of Electrode Degredation Within Lithium-Ion Batteries During Prolonged Use, D. Williams, p. 96
5:30 pm – 6:00 pm		Italmatch Chemicals – Streamlining Metalworking Fluid Development: A Package System for Success, W. Harwood, p. 95	Efficiency and Range Determination Aspects for Fluid Development of Battery Electric Vehicles, T. Wellmann, p. 96

SESSION 3K
Metalworking Fluids III
Room 201A

Environmental Advantages of Sulfur-Containing EP Additives in Metalworking Processes, W. Rehbein, p. 84

How To Design A Sustainable Metalworking Fluid Formulation Using Renewable Base Fluids, J. Ziobro, p. 84

Pick a PAG, Any PAG: Selecting Polyalkylene Glycols for Synthetic Coolants, Z. Magness, p. 84

Total Rehab of a Metalforming Fluid System in a Tube Mill Machine, A. Cardenas, p. 85

Break

Development of a Benchtop Tribological Test to Emulate Metal Cutting, S. Ashir Sajid, p. 85

Boundary Lubricant Additive Response Comparisons Between Aluminum and Copper Alloys Using Twist Compression Tests (TCT), T. McClure, p. 85

The Aminolysis and Hydrolysis of Esters in Water-Dilutable Metalworking Fluids, K. Zhong, p. 85

SESSION 3N
Nanotribology III
Room 202B

Invited Talk: Superlubricity – Toward Design of Zero-Friction and Zero-Wear Materials, D. Berman, p. 85

Speed Dependence of Friction in the Structural Superlubricity Regime, W. Oo, p. 85

Role of Contact Line in Structural Lubricity Breakdown, H. Gao, p. 86

Break

Single-Asperity Sliding Friction Across the Super-conducting Phase Transition, A. Schirmeisen, p. 86

Investigating Nanotribological Behavior of Graphitic Surfaces in the Binary Mixtures of Hexadecane and Cyclohexane, P. Nalam, p. 86

Connecting Interfacial Structure and Friction for Graphene-Based Interfaces, L. Yuan, p. 86

8:00 am – 8:30 am

8:30 am – 9:00 am

9:00 am – 9:30 am

9:30 am –10:00 am

10:00 am – 10:30 am

10:30 am – 11:00 am

11:00 am – 11:30 am

11:30 am – 12:00 pm

SESSION 4K
Metalworking Fluids IV
Room 201A

Assessing the Functional Lubricity of MWFs by an Innovative Tool, A. Schneider, p. 96

Performance Testing of Sulfur-Based Estolides in a Full Metalworking Fluid Formulation with Comparison of Other Commercialized Sulfur-Based Additives, M. Lutz, p. 96

Exhibitor Appreciation Break

Post Machine Cleaning – How to Pick the Right Surfactant for the Job, A. Milton, p. 97

Synergy of Polymeric Esters in Synthetic Metalforming Fluids, A. Yoder, p. 97

Polyglykol as Performance Wear Lubricant & Synergism with EP Additives on Net Oil Metalworking Fluid: Part 2, E. Lima, p. 97

Next Generation Multi-Metal Wire Drawing Fluids, K. Havelka, p. 97

Metalworking Fluids Business Meeting – 6:00 pm

SESSION 4L
Tribochemistry I
Room 201B

Synergistic Effects of Antifriction and Antiwear Additives on the Tribological Behavior of Lubricants Derived from Plastic Wastes Under Boundary Lubrication, P. Deshpande, p. 97

Synergistic Interactions Between Bio-based Oleate Ester and Low-Concentration ZDDP Under Reciprocating Contacts, J. Shu, p. 98

Exhibitor Appreciation Break

Mechanochemistry Study of ZDDP Antiwear Additives, L. Fang, p. 98

Influence of the Organic Moiety on the Tribological Properties of MoS_2: Glycol Hybrid Nanoparticles-Based Dispersions, F. Dassenoy, p. 98

The Influence of Slide-Roll Ratio on Glycerol Oleate Tribofilm Formation in the Boundary Lubrication Regime, M. Homayoonfard, p. 98

In Situ Carbon Tribofilm Formation Given by a Novel Organic Friction Modifier, W. Song, p. 98

SESSION 4N
Nanotribology IV
Room 202B

Invited Talk – Molecular Friction Studied by Stereographic Force Spectroscopy, B. Balzer, p. 100

Exhibitor Appreciation Break

Nanotribology Business Meeting

2:00 pm – 2:30 pm

2:30 pm – 3:00 pm

3:00 pm – 4:00 pm

4:00 pm – 4:30 pm

4:30 pm – 5:00 pm

5:00 pm – 5:30 pm

5:30 pm – 6:00 pm

TUESDAY

Session 3A | 101A

Lubrication Fundamentals III: Friction Modifiers

Session Chair: Nicole Doerr, AC2T research GmbH, Wiener, Neustadt, Austria

Session Vice Chair: Ramoun Mourhatch, Chevron Oronite LLC, Richmond, CA

8:00 am – 8:30 am

3811668: Friction Reduction Performance of Nanodiamonds in Presence of Organic Friction Modifier

Afrina Khan Piya, A. Al Sheikh Omar, Liuquan Yang, Ardian Morina, University of Leeds, Leeds, West Yorkshire, United Kingdom; Nazanin Emami, Luleå University of Technology, Luleå, Sweden

Using pin-on-disc tribometer at 50°C and 80°C, tribological performance of nanodiamonds (NDs) with Glycerol monooleate – GMO: organic friction modifier, Zinc dialkyldithiophosphate – ZDDP: anti-wear additive, and their combination was investigated with PAO: Polyalphaolefin synthetic oil. For binary additive system (except nanodiamonds), coefficient of friction represented similar values of individual additives. Surface adsorption of organic friction modifier, GMO over ZDDP and/or ZDDP breakdown products are responsible for observed tribological reaction. Nevertheless, nanolubricants showed remarkable synergistic effect on friction reduction at higher temperature through forming chemically reactive additive layers in which nanodiamonds were mechanically interlocked. Addition of 0.05 wt% NDs to binary lubricating system, reduced COF approximately 60% at 80°C. Findings from the investigation of disc surfaces after tribological tests were substantiated by static SIMS, SEM, EDX, AFM and TEM.

8:30 am – 9:00 am

3831281: Research on the Activation and Performance Retention of Organomolybdenum Additives

Brian Casey, David Boudreau, Vanderbilt Chemicals, LLC, Norwalk, CT

Organomolybdenum additives can provide significant friction reduction and wear protection to lubricating oils and greases through the formation of molybdenum disulfide (MoS_2). Whereas molybdenum dialkyldithiocarbamates (MoDTCs) and dialkyldithiophosphates (MoDTPs) can form MoS_2 directly, sulfur- and phosphorus-free molybdate ester (MoEster) additives must first sequester sulfur from other sources within a lubricant. The formulation style can affect both molybdenum activation to form MoS_2 as well as performance retention by maintaining the MoS_2 film. This presentation will focus on how various sulfur-containing additives can be used to influence the performance profiles of MoEsters in engine oils.

9:00 am – 9:30 am

3834157: Effect of Organic Friction Modifiers on Friction and Wear of HDDEO Formulations

Alexei Kurchan, Cargill Inc., Plainsboro, NJ

Drive for sustainability is strongly influencing lubricants technology. For new proposed diesel engine oil category (PC-12) Improvements requested include lower viscosity oils to support requirements for fuel economy for certain engine models, improved aftertreatment capability potentially lowering sulfated ash, phosphorus, and sulfur (SAPS) levels even further, and improved oxidation stability extended oil drain interval. With increased focus on fuel economy and wear organic friction modifiers will play an important role in lowering frictional losses and providing boost to wear performance. Use of traditional antiwear, extreme pressure additives, and inorganic molybdenum-based friction modifiers increases total levels of SAPS and might not provide desired benefit for the duration of oil drain interval. We will present our work on efficiency of various organic friction modifiers in diesel oils based on tribological bench tests and aged oils performance in simulated oxidation.

9:30 am – 10:00 am

3812392: Study of the Interaction Between Esters and Different Friction Modifier Additives in a Group IV Base Stock

Gerard Cañellas, Ariadna Emeric, Àngel Navarro, Lluís Beltran, Industrial Química Lasem, Castellgalí, Spain; Mar Combarros, IQL, Castellgalí, Barcelona, Spain; Montserrat Vilaseca, Eurecat, CTM, Manresa, Barcelona, Spain; Jordi Vives, UPC, Manresa, Barcelona, Spain

The replacement of conventional lubricants by esters is an alternative to improve formulations. Esters provide a low environmental impact and at the same time excellent lubricity features, high solubility of additives, good viscosity index, and high hydrolytic and thermal stability. Friction modifiers and extreme pressure additives are extensively used to save energy and increase operational life in machine components. In this study the lubricity of a Group IV base oil containing ester and various benchmark friction modifiers and/or extreme pressure additives is measured to evaluate the interactions between the mixture components. The tribological performance is discussed based on the tabulation of the friction coefficient using a MTM and on the measurement of the wear rate from wear scar of the experimental studies using an optical profilometer. In general, results show synergies between ester and additives reducing wear rate and friction coefficient.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3813355: Bench Friction Evolution of Engine-Aged Oils

Brendan Miller, Ramoun Mourhatch, Chevron Oronite Company, Richmond, CA

Automotive fuel efficiency has been, and will continue to be, a key topic for OEMs and lubricant suppliers. As lubricant viscosities continue to drop for hydrodynamic gains in fuel economy, surface friction reduction will play a larger role in fuel economy performance. It is well known that current organic and organometallic FMs can provide fuel economy performance in fresh conditions, but their performance fades as the oils age in the engine. The authors show friction performance depletion over time for various organic friction modifiers aged in an engine.

11:00 am – 11:30 am

3808868: Measuring the Frictional Behavior of Lubricants with an Antiwear Additive and Different Friction Modifiers

Katherine Tomlinson, University of Sheffield, Sheffield, United Kingdom; Nick Morris, Paul King, Loughborough University, Leicestershire, United Kingdom; Tom Slatter, University of Sheffield, Sheffield, United Kingdom

Frictional losses from the piston assembly in internal combustion engines is an area of interest for improving efficiency and reducing emissions. This study measured the frictional behavior of lubricants with antiwear additives and different friction modifiers at a range of temperatures on a Nickel Silicon Carbide coated cylinder liner. A novel motored reciprocating tribometer isolated the friction at the interface between cylinder liner and oil control ring. Three lubricants were tested, all with the same 3% dispersant concentration and 1% ZDDP anti-wear additive, the first with no friction modifier, the second with inorganic friction modifier (molybdenum dithiocarbamates) and the third with

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organic friction modifier (amide). Results indicate that the organic friction modifier in combination with ZDDP does not reduce friction compared to the molybdenum dithiocarbamates, showing the importance of friction modifier selection with anti-wear additives on metal matrix composite coatings.

11:30 am – 12:00 pm

3804989: Scaling of Friction Behavior in the Mixed Lubrication Regime through a Modified Hersey Number

Erik Hansen, Gerda Vaitkunaite, Johannes Schneider, Peter Gumbsch, Bettina Frohnapfel, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The friction behavior of lubricated contacts is commonly quantified by the Stribeck curve. Subsequently, the Hersey number is often used to generalize the Stribeck curve, thus allowing its scaling to other operating conditions. However, this only works in the hydrodynamic lubrication regime and fails in mixed lubrication, especially in cases of varying normal loads or contact geometries. Through a validated digital twin of a pin-on-disc tribometer, this behaviour is demonstrated for conformal contacts. As a result, a modifed Hersey number is suggested such that the scaling of the Stribeck curve in the mixed lubrication regime is preserved, which can become useful in the application of e.g., surface texturing. While this presentation focuses on a numerical approach and its employment of measured roughness topographies in the implemented homogenized MEHL-JFO model, the obtainment of the complementary experimental data along with further investigations is topic of submission 3805242.

Session 3B | 101B

Rolling Element Bearings III

Session Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

Session Vice Chair: Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH

8:00 am – 8:30 am

3833592: Influence of Residual Stresses Due to Cold Forming on Stainless Steel Bearings

Alexander Bodewig, Florian Pape, Gerhard Poll, Leibniz University Hannover, Garbsen, Lower Saxony, Germany

In this contribution, a simulative bearing fatigue life model based on Ioannides and Harris is transferred to stainless steel angular contact ball. Deformation-induced residual stresses are considered to model the strain hardening by cold forming of metastable austenitic steels due to compressive residual stresses due to the increase in volume of the martensitic phase, which has a positive effect on a components' fatigue life. In addition to rolling motion and sliding in the longitudinal direction, additional shear stresses induced by the spin of the balls on the raceway are transmitted in angular contact ball bearings. Calculations with varied shear stress distributions are carried out for different bearing loads to quantify their influence on the bearing service life. The residual compressive stresses will be superimposed in the simulation. The calculations are validated with results from fatigue life tests.

8:30 am – 9:00 am

3833799: Influence of High Loads on the Fatigue Life Behavior of Rolling Bearings

Simon Dechant, Institute for Machine Design and Tribology, Hanover, Germany

In practical applications, premature bearing failures may occur. One reason for this can be special events that cause high loads to occur for a short time. In order to investigate the influence of short-term high loads on the fatigue life of cylindrical roller bearings, experimental life tests were carried out. From single-stage tests with different load levels, an experimental Wöhler line can be determined as a reference value. In addition, two-stage tests were performed in which a high load phase was imposed at the beginning. Subsequently, the load was reduced to the base load level and the life test was operated until failure. The duration of the high load phase was varied in four different test series. The comparison of the one- and two-stage tests shows the influence of the high load phase on the fatigue life as a function of the high load duration.

9:00 am – 9:30 am

3831513: An Investigation into Rolling Contact Fatigue Performance of Aerospace Bearing Materials

Steven Lorenz, Farshid Sadeghi, Purdue University, West Lafayette, IN

The objectives of this investigation were to evaluate aerospace-quality bearing steels experimentally and analytically in rolling contact fatigue (RCF). To achieve these objectives, 3 aerospace-quality bearing materials were manufactured into test coupons for torsional fatigue and rolling contact fatigue (3 ball-on-rod). First, 3 ball-on-rod tests were performed to qualify each material's RCF performance. Next, torsional fatigue experiments were conducted and the S-N data from these experiments was supplied to the developed analytical RCF finite element model to calibrate the damage rate equation, which considered the Fatemi-Socie as the failure criteria. The analytical model used continuum damage mechanics to simulate material degradation as a function of cycle. It was observed that good corroboration existed between the analytical simulation life predictions and the 3 ball-on-rod experimental results, with both sets of results establishing which material performed superior in RCF.

9:30 am – 10:00 am

3813418: Predicting Surface Pitting Fatigue Behavior Using Torsion Fatigue Characteristics

Kushagra Singh, Farshid Sadeghi, Purdue University, West Lafayette, IN

This work presents fundamental findings on equivalence of a surface pitting fatigue and torsion fatigue. A Thrust Bearing Surface Pitting Test Rig (TBSPR) was developed and utilized to conduct rolling contact fatigue experiments on case carburized gear steel. These tests were conducted at different contact pressure and fatigue cycles, followed by optical profilometry to determine the presence of surface pits. The results were used to develop the SN curve for surface pitting. Torsion fatigue experiments were conducted on the same material, and the SN curves of both modes of failure were compared. The results showed remarkable similarities between the shapes of these SN curves. This investigation shows that the surface pitting characteristics can be predicted by conducting much simpler, and faster, torsion fatigue tests.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3834141: Effect of Surface Roughness & Lubrication Regime on Bearing RCF Life Using Computational Modeling Tool

Behrooz Jalalahmadi, Nick Weinzapfel, Sentient Science, Buffalo, NY

It is widely known that surface roughness of bearing races can significantly affect rolling contact fatigue (RCF) life. We utilize our DigitalClone for Engineering (DCE) bearing modeling tool to investigate the effect of surface roughness on lubrication regime, contact pressure profile and bearing RCF life. DCE is a physics-based RCF life prediction model which has been developed considering contact stresses, material microstructure, crack initiation mechanisms, damage mechanics, and probabilistic methods. To demonstrate the validation of DCE modeling tool, two different bearing types are studied under RCF loading: a) off-the-shelf AISI 52100 cylindrical roller bearing (CRB), b) custom-made M50 angular contact ball bearing (ACBB). We perform both experimental RCF testing and computational RCF modeling using our DCE modeling tool. Due to variation of surface roughness of bearing races, two different lubrication regimes of mixed-EHL and boundary lubrication are created.

11:00 am – 11:30 am

3812340: Wear Induced Changes in Surface Topography During Running-in of Rolling-sliding Contacts

Maruti Sai Dhiraj Sakhamuri, Terry Harvey, Robert Wood, University of Southampton, Southampton, United Kingdom; Bernd Vierneusel, Schaeffler Technologies AG & Co KG, Schweinfurt, Germany

Running-in in rolling-sliding contacts under mixed-friction conditions involves asperity smoothing through mild wear and plastic deformation. To improve the prediction of service life or friction of bearings under mixed-friction conditions, knowledge of surface topography changes during running-in and their dependence on the operating condition is key. Therefore, this study investigates one of the operating variables, slip. AISI 52100 steel specimens were tested in a PAO base oil at various slide-roll ratios in a mini traction machine operating under the mixed lubrication regime. A novel method of pre and post-test surface relocation with 3-D optical profilometry and SEM was implemented. The near surface region was investigated using FIB. The results exhibit the rapid nature of running-in. Asperity removal and excessive plastic deformation due to slip are shown at high magnification. FIB analysis links this plastic deformation in the running-in stage to non-ideal bearing performance.

11:30 am – 12:00 pm

3812773: Investigation on Strength of Steel and Silicon Nitride Rollers Against Fracture

Nikhil Londhe, Aaron Muhlenkamp, Hiroshi Marunaka, The Timken Company, North Canton, OH

Recent demands for optimized mechanical power transmissions have led to use of smaller size bearings operating under higher contact loads. For successful performance it is necessary to develop stress guidelines for rolling bearings to prevent roller fractures and crushing under high contact loads. This study presents experimental and numerical investigation of strength of steel and silicon nitride cylindrical rollers against fracture and ultimate crushing. Steel rollers were manufactured using different heat treatments and silicon nitride rollers were hot pressed. Because of high hardness of silicon nitride, experiments were carried out with special tooling. Profiles were designed on the parts to concentrate stresses in specific regions, and which become crack initiation sites. Contact stresses were estimated using numerical simulations. Experimental results show good agreement between strength and fracture properties of steel rollers manufactured using different heat treatments.

Session 3C | 102A

Fluid Film Bearing I

Session Chair: Cori Watson-Assa, GE Aerospace, Cincinnati, OH

Session Vice Chair: Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA

8:00 am – 8:30 am

3804785: An Optimized Normalization of the Inlet Computation Zone for Isothermal EHL Contacts

Yuko Higashitani, Sanemasa Kawabata, Denso Corporation, Showa-cho, Kariya-shi, Japan; Marcus Björling, Andreas Almqvist, Luleå University of Technology, Luleå, Sweden

Lubricated contacts in cam mechanisms, rolling bearings, etc. typically operate under elastohydrodynamic lubrication (EHL). The useful life is closely related to the oil film thickness, suggesting that the possibility of predicting it is an important facility when developing machine elements including EHL contacts. Most of the numerical calculation methods for EHL film thickness, employ a fixed multiple of the Hertzian radius for the normalization of the computational domain. However, the solutions obtained might be numerically starved, especially under low-load, high-speed conditions. The present fully coupled FEM-based model, incorporates an optimized normalization of the inlet length, ensuring appropriate meshing over a wide range of operating conditions, efficiently avoiding numerical starvation. The present method can, therefore, be used to obtain accurate EHL solutions over a wide range, including the transition regions between high-load and low-load, high-speed and low-speed.

8:30 am- 9:00 am

3811673: Experimental Investigation on Thrust Bearing Cooling Arrangement Within Tilting Pads

Farooq Najar, G A Harmain, NIT Srinagar, Srinagar, J&K, India

The present paper describes the influence of cooling circuitry within the thrust element (tilting pads) in a thrust bearing. The experimental set up was indigenously designed with various types of cooling circuits. One of the circuits designated as circuit-II has been installed in the set up and tests were carried out. During testing, the inlet temperature of lubricant (SAE 30) was maintained at 40oC, the load and whirl combination was set at 5 kN and 1400 rpm, respectively. The results has shown a significant drop in the oil film temperature which in turn helps the thrust bearing set up to withstand for utmost load condition.

9:00 am – 9:30 am

3804389: Static and Dynamic Behavior of a Porous Bearing Lubricated by Nanofluids

Benyebka Bou-Saïd, INSA Lyon, Villeurbanne, France

We present a numerical simulation model of porous journal bearings considering the fluid film – poroelastic matrix interaction and the non-Newtonian rheological behavior of nano lubricant consisting of base fluid and nanoparticles (NPs). The flow of the nano lubricant in the porous medium is modeled by the modified Darcy's law where the Beavers–Joseph slip condition is applied at the fluid film-porous matrix interface. The hydrodynamic pressure induced deformation of the fluid film- porous matrix interface is calculated by using a simplified analytical model – "Thin Elastic Liner Model". The bearing porosity is introduced into the Reynolds equation by means of the Morgan-Cameron approximation.

3C

9:30 am – 10:00 am

3811830: Dynamic Analysis of Finite Porous Journal Bearing Considering Cavitation

Elizabeth Clifford, The University of Akron, Akron, OH

A novel approach to modeling multiphase fluid film within a porous journal bearing was presented. Pseudo cavitation contributed a gas phase to the liquid within the bearing. The physics-based approach conserved mass while solving the coupled Rayleigh-Plesset (RP) and Reynolds (RE) equations to produce the time-dependent void fraction of the fluid film. The void fraction was used to update density and viscosity properties of each fluid grid cell. The three-dimensional pressure distribution dictated the injection velocity from the porous bushing. The work presented a novel analytic solution for pressure distribution in the porous medium which coupled to the RP-RE equations. Effects of cavitation on the fluid film on pressure distribution and bearing stability were investigated. Select cases were compared with previous work for approach validation.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3811880: Thin Film Momentum and Energy "Bulk Flow" Equations with Velocity and Temperature Profiles

Mihai Arghir, Emanuele Giampaolo, Universite de Poitiers, Futuroscope Chasseneuil, France

The momentum "bulk flow" equations are a mathematical model for the thin film flow with large, reduced Reynolds numbers when convective inertia forces are important. The original equations were deduced by considering that the inertia forces do not modify the parabolic velocity profile that prevails in low to moderate Reynolds number laminar flows. The present work uses a fourth order polynomial for describing the velocity profile in thin film flow dominated by convective inertia. The five coefficients of the velocity profile are expressed by using the average velocity and by imposing the no-slip boundary conditions and the wall shear stresses. A similar approach is adopted for the temperature profile needed in the energy "bulk flow" equation and is coupled with the momentum "bulk flow" equations. The new equations are solved for a slider operating at high reduced Reynolds number and the results are compared with the solution of the classical Reynolds, "bulk flow" and energy equations.

11:00 am – 12:00 pm

3897835: Invited Talk – Fundamentals of Fluid Film Bearings Used in Turbomachinery Operated at Extreme Conditions

Keun Ryu, Hanyang University, Ansan, Gyeonggi-do, Republic of Korea

High-performance turbomachinery requires fluid film bearings, in compact units of superior reliability and durability, because of their distinctive advantages over conventional off-the-shelf rolling element bearings which cannot meet unique demands for bearings used in extreme and harsh conditions. A sound understanding of bearing operating principles is essential for design, development, and testing of modern turbomachinery. Extensive experience and knowledge in practical aspects of bearing characteristics are important when making critical decisions for turbomachinery in propulsion and power systems. This invited talk presents the fundamentals of fluid film bearings while mainly focusing on the practical features of both journal and thrust bearings. Failure modes and their mechanisms will be discussed comprehensively from real machinery operation and test rig demonstration. Experimental techniques and theories for identification of bearing forced performance will also be discussed.

Session 3D | 102B

Materials Tribology III

Session Chair: Mary Makowiec, Pratt & Whitney, East Hartford, CT

Session Vice Chair: Santiago Lazarte, Florida State University, Tallahassee, FL

Session Starts at 8:30 am

8:30 am – 9:00 am

3834326: 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 countersurfaces 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.

9:00 am – 9:30 am

3835100: Qualitative Analysis of Transfer Film Properties on Wear Performance of Metal-Filled Fluoropolymer Composites

Faysal Haque, Mark Sidebottom, Miami University, Oxford, OH

Unfilled Polytetrafluoroethylene (PTFE) has a low friction coefficient, but also a high wear rate (K~10^{-4} to 10^{-3} mm^3 /Nm). Over the years, PTFE has been composited with different materials such as α-Al_2O_3, GeO_2, BeO, activated carbon nano fillers etc. to reduce the wear rate by ~10^4 against 304 SS. These are known as ultra-low wear materials. Recently three metal fillers (Cr, Ti, Mn) particles were able to achieve ultra-low wear rate in Brass 260 but mixed performance against 304 SS. This discovery of new fillers and counter body motivated to explore other counter bodies such as Cu 110, Zn galvanized steel to find the relationship between wear rate and counter body hardness. This will help us to understand how a hard particle like Cr was able to form stable transfer film on Brass 260 but did not perform well against 304 SS. For this presentation, the PTFE-Cr is tested with different counter bodies and the quality of the transfer film was analyzed.

9:30 am – 10:00 am

3860120: Don't Worry, It Will Get Better: How (Particle) Break-Ups Improve Wear in PTFE Composites

Mark Sidebottom, Sifat Ullah, Miami University, Oxford, OH; Tomas Babuska, Nathan Heckman, Brad Boyce, Sandia National Laboratories, Albuquerque, NM; Brandon Krick, Florida State University, Tallahassee, FL

Unfilled PTFE is limited as a solid lubricant due to high wear (K~10^{-3}-10^{-4} mm^3/Nm). One of the most common fillers used to reduce wear is α-Al_2O_3 particles, with certain Al_2O_3 particles reducing the wear rate of unfilled PTFE by ~10^4. Past work showed the importance of particle size, composition and porosity on wear of these systems, but no quantitative measure existed to relate the properties of the filler particles to wear.

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In-situ nanoindentation experiments on different sets of filler particles, tribological testing and surface analysis were used to develop a new metric that relates composite wear rate to the apparent fracture toughness of the reinforcing particles. This framework explains the ~100x difference observed in wear between low apparent fracture toughness reinforcing fillers versus high fracture toughness fillers. This model helps the selection of filler particles likely to promote ultralow wear PTFE composites without complete reliance on empirical testing.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3834303: On the Dry Sliding Wear of PEEK-PTFE Composites

Elizabeth Anders, Harman Khare, Gonzaga University, Spokane, WA

The addition of nanoscale metal-oxide fillers to polytetrafluoroethylene (PTFE) has been shown to be highly effective in reducing wear of unfilled PTFE. Despite their ability to reduce wear of PTFE by almost four orders of magnitude, an increase in wear is observed, for instance, when composites are run at high temperatures, in the absence of ambient humidity, etc. In contrast, polyether ether ketone (PEEK) is recognized as a more robust filler for PTFE in terms of achieving wear rates which are lower by over four orders of magnitude compared to unfilled PTFE, under a wider range of conditions. This work reports on the results of dry sliding wear with PEEK-PTFE composites under conditions which are otherwise known to disrupt low wear of PTFE composites filled with metal-oxide fillers. Results from tribological, chemical and morphological characterization of PEEK-PTFE sliding interfaces are presented, giving insight into the mechanochemical mechanisms driving variations in wear rates.

11:00 am – 11:30 am

3834238: Tribological Behavior of PTFE-PEEK: Influence of Composite Processing

Kylie Van Meter, Brandon Krick, Florida State University, Tallahassee, FL; Christopher Junk, CJ Ideas LLC, Wilmington, DE

Polytetrafluoroethylene (PTFE) is widely used in tribology applications as a solid lubricant; it is thermally stable, chemically inert, and has very a low surface energy and coefficient of friction (<0.1) but suffers from a high wear rate. PTFE filled with poly ether ether ketone (PEEK), a high-performance thermoplastic, has been shown to achieve ultralow wear rates ($K < 10^{-7}$ mm^3/Nm) and low friction (<0.2). PTFE-PEEK composites can exhibit inconsistent tribological behavior from sample to sample, with wear rates of compositionally identical samples varying by multiple orders of magnitude. In this work, these variations are found to be influenced by processing conditions such as composite mixing and sintering conditions. Tribological and mechanical characterization of composites fabricated with varying processing conditions, along with chemical analysis of the sliding interface, is used to elucidate the impact of composite processing on the tribological behavior of PTFE-PEEK.

11:30 am – 12:00 pm

3830056: Design of PEEK-Based Composites for Multifunctional Applications

Surojit Gupta, Shawn Ruggiero, Caleb Matzke, University of North Dakota, Grand Forks, ND; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Polyether ether ketone (PEEK) is an important polymer thermoplastic material which can be used in different demanding applications. Brittleness and poor tribological behavior are some of the issues with PEEK-based compositions. In this study, different additives like MAX and MAB phases will be explored to enhance the mechanical and tribological properties. We will present detailed microstructural characterization of these composites. The mechanical behavior of these composites will be also presented. In addition, tribological behavior of these composites in dry and lubricated conditions will be presented by ball-on-disc method. Detailed analysis of wear tracks after tribological measurements will be presented. Finally, these results will be compared with different PEEK-based composites.

Session 3E | 102C

Condition Monitoring III

Session Chair: Greg Horwich, Gastops, Dartmouth, Nova Scotia, Canada

Session Vice Chair: TBD

8:00 am – 8:30 am

3816883: Wear Metal Alarm Limits Versus Trending

Evan Zabawski, Eurofins TestOil, Strongsville, OH

Oil analysis users commonly ask, "How much wear is normal/abnormal?", and they tend to get a range of answers from generic to misleading. This presentation will begin by clarifying why that question poses such difficulties in getting a straight answer using clear examples applicable to any type of asset. Variables such as viscosity, sump volume and oil service all play a vital role in establishing reasonable limits, which is why there is no one set of published limits. Even attempts at using rate-of-change are fraught with inaccurate assumptions that mask real issues. This presentation will conclude by showing how trending avoids all the common pitfalls of the other methods.

8:30 am – 9:00 am

3831987: Rapid Identification and Quantification of Ethylene and Propylene Glycol in Engine Coolant by Gas Chromatography

Nicholas Lancaster, Cory Schomburg, Lee Marotta, Leeman Bennington, PerkinElmer, Waltham, MA

Determining the glycol type and concentration of an engine coolant is a useful analytical test for in-service testing laboratories to both identify the coolant type and determine whether the coolant is fit for its intended purpose. Standard specifications for engine coolants prescribe that a glycol concentration between 40-60 %v/v in water of suitable quality, will function effectively during winter and summer. As such, repeat testing to assess the glycol content over the lifespan of the coolant is required to avoid problems. Commonly, glycol content is determined manually using a refractomer, either in the field or in the laboratory. Gas Chromatography is an alternative analysis technique for glycols that allows for automation of large batches of coolant samples and can identify the glycol present in the coolant in addition to determining its concentration. With correct optimization, analysis time can be kept as low as five minutes per sample with minimal sample preparation.

9:00 am – 9:30 am

3832529: Filter Element Construction and Electrostatic Discharge Polarity in Hydraulic Systems

John Duchowski, Hydac FluidCareCenter GmbH, Sulzbach, Saar, Germany; Keith Windebank, Tobias Daley, Hydac Technology Ltd., Witney, Oxfordshire, United Kingdom

The electrostatic discharge (ESD) phenomena in hydraulic and lubricating systems are well understood. ESD arises because of energy difference between the glass fiber filter material and the hydrocarbon fluids employed in these systems. Charges separate because of these energy differences; no friction is required. This energy difference is on the order of 30 Jm—^{2}. The glass fiber at far-left end of the triboelectric series acts as an electron donor and the hydrocarbons towards the middle as

an acceptor. In most applications a negative charge is measured in the fluid. At the 2018 STLE Annual Meeting, we reported polarity reversal because of different oil formulations. The case involved an oil blend with a large content of naphthenic stock with specialized additives for low temperature applications. We now report polarity reversal because of differences in filter element construction. The events were observed on hydraulic mules employed for supplying power to aircraft on the ground.

9:30 am – 10:00 am

3833748: An Automated Approach to Gravimetric Dilution for Lubricant ICP Sample Preparation and Analysis

Steven Twining, Elemental Scientific, Inc., Navasota, TX

Inductively Coupled Plasma gravimetric sample preparation often requires the most skilled analysts performing high precision dilutions by weight, often in a hood, for hours on a daily basis. A new automated technology has been developed that dilutes samples accurately and precisely. This highly flexible system prepares a variety of samples over a wide viscosity range. Combined with a second technology that incorporates non-mechanical gas infusion homogenization, automated lubricant gravimetric sample preparation is now possible.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3833834: Asset Condition Assessment – Field Application

Marc Yarlott, Veolia North America, Vancouver, WA

Understanding an asset's life cycle status is essential for asset management because decisions about system capacity, asset repair/replacement, and priorities can all be established with accurate asset life cycle status ranking. Asset life cycle status is directly driven by the asset condition and the methods used to establish the condition assessment. This case study will examine asset condition assessment field gathering methods and data collection in a computerized maintenance management system (CMMS), including mobile data collection tools. Learning objectives include: 1.) Field measurement methods, 2.) Developing a repeatable condition assessment rating criteria for a complex asset and 3.) Workflow for collecting, analyzing, and updating the condition scoring in CMMS (Infor EAM Example).

11:00 am – 11:30 am

3812939: Real-Time Online Determination of Lubricant Remaining Useful Lifetime and Detection of Common Lubrication Contamination Events

Timothy Mack, Greg Horwich, Gastops, Dartmouth, Nova Scotia, Canada

The extent to which online lubricant condition monitoring and real-time predictive maintenance will be adopted is contingent on the development of on-equipment sensors that are rugged, cost-effective, and miniature and analyte specific. It will also be desirable that the underlying physics of sensor operation should be sufficiently well-understood to properly harness statistical data analytics tools and scrutinize their predictions. This paper presents examples of suitable sensor technologies that can address the criteria above. Such sensors can be employed both to identify specific common lubricant contamination events, such as coolant or fuel contamination, as well as provide a real-time estimate of lubricant remaining useful lifetime based on in-situ detection of antioxidant degradation species. By combining data from complementary sensors, improved prognostic maintenance models can be developed, leading to equipment reliability improvements as well as maintenance cost reductions.

11:30 am – 12:00 pm

3831245: The Impact of Oil Additive Types and Their Content on the Oil Electrical Conductivity

John Duchowski, Andrei Wenzel, Hydac FluidCareCenter GmbH, Sulzbach, Saar, Germany

An investigation to determine the impact of oil additive types and their content on the oil electrical conductivity has been carried out for several additive types blended into the oils of different API Groups at different concentrations. The investigation was carried out systematically, and in a step-wise fashion. Representatives from all the four-hydrocarbon-based API oil groups were selected as were representative additive types. The latter included antiwear/extreme pressure, antioxidant, and viscosity index improver. In order to delineate the impact of each, the additives were blended in individually and in regularly increasing concentrations levels that are typically employed in standard formulations. The results were quite surprising and will be described in detail during the technical session.

Session 3F | 103A

Environmentally Friendly Fluids II

Session Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

Session Vice Chair: Daniel Garbark, Battelle Memorial Institute, Columbus, OH

8:00 am – 8:30 am

3900486: Renewable Base Oils for Sustainable Lubricants: A Transparent & Scientific Approach

Ward Huybrechts, Lotje Smolders, Oleon, Gent, Belgium

Renewable base oils are seen as a sustainable alternative in the production of lubricants. However, the question of whether they are always the most sustainable option is still up for debate. To approach the issue of sustainability in a scientific manner, life cycle assessments (LCA) are performed. Today, most emphasis is put on product carbon footprint (PCF). There are both limitations and challenges to LCA analysis and carbon footprint calculations as they are based on assumptions that are open for interpretation. On top of that, the impact of the renewable carbon content (biogenic), should also be considered. Reporting these values can differ from one company to another and can sometimes result in negative PCFs as there are no explicit rules on how to include renewability in the LCA. Insights will be given in which different assumptions, interpretations and reporting are currently being used in the industry and which ones seem to be the most scientific and transparent.

8:30 am – 9:00 am

3811270: Viscosity Modifiers with an Environmental Acceptable Design and an Improved Performance

Mar Combarros, Marc Alumà, Taro Ehara, IQL, Castellgalí, Barcelona, Spain; Ariadna Emeric, Gerard Cañellas, Àngel Navarro, Industrial Química Lasem, Castellgalí, Spain

New environmentally acceptable viscosity modifiers have been developed as an alternative and improving performance of common additives in the market. These specifically designed organic polymeric structures show good thickness efficiency, offer good lubricity, volatility, and especially good shear stability. We have tested shear stability using the KRL tapered roller bearing shear stability test, evaluating the change in viscosity and the molecular breakage. A higher shear stability compared to other products in the market and a dependence on the size

of the molecule was found. Lubricity was tested using SRV and MTM obtaining a reduction in coefficient of friction. Furthermore, when the new viscosity modifiers are used, much lower volatilities are observed by thermogravimetric analysis in the formulations. Finally, compatibility with other common viscosity modifiers and additives was investigated.

9:00 am – 9:30 am

3811333: Degradation and Lubrication of Stern Tube Seals – Understanding Seal Durability

Tom Briggs, Philippa Cann, Marc Masen, Imperial College London, Oxford, United Kingdom

The stern-tube seal is the ship component responsible for retaining the stern-tube bearing lubricant and excluding seawater. The introduction of environmentally acceptable lubricants has created new challenges for seal manufacturers- namely a significant drop in reliability due to surface damage at the shaft-seal interface. Little research has been carried out on seals that operate in seawater-oil, although there is significant work into air-oil seals. The project is an experimental study of stern-tube seal degradation operating in a seawater-oil environment. Results from a novel bench test, simulating the seal operation, will be presented. The test uses a glass ring as the shaft element which allows the use of techniques to measure film thickness, initiation of surface damage and composition of the interfacial film using in-situ techniques. Post-test analysis of aged seals is also possible using SEM and nano-indentation. Full-scale tests will also be presented for validation purposes.

9:30 am – 10:00 am

3830387: Achieving Performance and Sustainability Objectives with Ester Technologies

Matthias Hof, Emery Oleochemiclas GmbH, Duesseldorf, NRW, Germany

Over the last years, sustainability has increased in importance in our industry. Stakeholders in our industry along the value chain continue to recognize and adopt the practice of being more sustainable and transparent about use of raw materials, CO_2 emissions, waste management and recycling potentials. This paper will highlight how finding the balance to achieve both performance and sustainability objectives in modern applications can be addressed by implementing proven as well as new ester technologies and strategies. The usage of existing renewable, bio-based but also petrochemical raw materials will play a major part in this development. Due to the highly flexible chemistry design of ester components and base stocks, this technology can play an important role in helping the formulating industry to reach their sustainability goals for all types of lubricant applications. Technical performance benefits along with more environmentally friendly properties will be discussed.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3804219: An Environmentally-Responsible Approach to Improving Your Heat Transfer Fluid Chemical Hygiene

Richard Beemsterboer, ORG CHEM Group LLC, Oak Lawn, IL

Thirty-years ago, heat transfer fluid (HTFs) manufacturers would encourage and provide full-system replacement of used HTFs with virgin fluid and dispose of the used HTFs without regard for the potential of remediating the used fluid. Times have changed. HTF users needed an alternative to dump and dispose of the used HTF by burning or landfilling and replacing it with virgin products. Processing a synthetic, high-temperature heat transfer fluid allows the user to have the foulants of the liquid removed or 'reclaim' the 'good' distillate and enhance the chemical sustainability of their organization by re-using a chemical in place of disposal. Reclaiming and recycling a heat transfer fluid for continued use is an economical, ecological, and responsible approach to specialty chemical management. This talk presents an alternative to disposing of and replacing an HTF with a more environmentally friendly way to extend the life of an HTF and meet sustainability and ESG initiatives.

11:00 am – 11:30 am

3831292: A New Safer and Sustainable Turbine Oil

Gregoire Herve, NYCO, Paris, France

Modern lubricants in particular state-of-the-art technologies need to reach performance. Sustainability is an additional requirement that becomes more and more important. Final users ideally desire non-hazardous materials with complete absence of safety & health risks combined with minimum impacts on the environment. Such a complete package becomes a challenging goal for industrial companies. Aviation turbine oils have been used since Second World War II. Despite technology & science evolution, those lubricants are still a major concern, as they still contain toxic components such as antiwear and antioxidants. Here is presented an original toxicity cross-evaluation combining modeling and experimental studies applied on the toxic substances leading to a safe- and risks-free formulation. Lastly, thermal and tribological evaluations highlight a similar level of high performance compared to existing oils. No trading-off was done implying that sustainability and performance can truly co-exist.

11:30 am – 12:00 pm

3869627: Eco-Sustainable Synthetic Ester Oil Formulations for Micro-Electromechanical Systems: Tribological Investigations

Nagendramma Ponnekanti, Anjan Ray, Ankit Pandey, Atul Singh, Indian Institute of Petroleum, Dehradun, Uttarakhand, India

We have developed a novel catalyst and method for producing new-generation lubricant formulations from indigenous raw materials for aircraft precision instruments and other components such as delicate bearings, gauges, chronometers, and clocks. The resulting biodegradable mineral oil-free lubricant formulations have excellent biodegradability, high viscosity index, low pour point, high flash point, excellent lubricity, good oxidative stability, excellent wear protection, corrosion inhibiting characteristics, and suitability for use with commercial additives. The developed bio-lubricant formulations are a superior alternative to known commercial products like conventional mineral oils, fluoroethers and PFPE-based lubricants having issues of toxicity, non-biodegradability, and durability. This paper will describe the synthesis, physicochemical characterization, and performance evaluations of biodegradable ester oils for precision instruments in the aerospace and defense sectors.

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Session 3G | 103B

Gears I

Session Chair: Chengjiao Yu, Hebei University of Technology, Tianjin, China

Session Vice Chair: Pinzhi Liu, ExxonMobil Research and Engineering, Annandale, NJ

8:00 am – 8:30 am

3810701: Pitting Detection in an Early Damage Stage for AI-Based Operating Strategies in Wind Power Drives

Lukas Merkle, Martin Dazer, Andreas Nicola, University of Stuttgart, Stuttgart, Germany

Gear failure caused by pitting is one of the leading reasons of downtime in wind turbines. An adaptive operating strategy applies a load reduction of a damaged tooth by the means of torque variation to increase the remaining useful life. For the highest possible increase of service life, a detection of pitting damage at an early stage during operation is necessary. To investigate the detection possibilities on the test rig, a test gearbox is developed. The tooth flanks of test gears are manufactured with artificial pitting damage at different stages. The test gearbox is equipped with various load and vibration sensors mounted at different positions of the housing. The sensors acquire a large amount of data, depending on the size of the damage. The test results are used to train deep neural networks for AI based plant operation. The experiments not only show at which stage pitting damage is detectable, but also form the data basis for AI based condition monitoring of wind power drives.

8:30 am – 9:00 am

3811272: Formulating for an Increasingly Complex Industrial Gear Landscape

Paul Norris, Helen Ryan, Afton Chemical Ltd., Bracknell, United Kingdom

Premium industrial gear products are now expected to meet an increasingly complex and demanding set of OEM and Industry specifications. These diverse specifications reflect a huge variety of end uses, ranging from small material handling systems to heavy duty industrial operations, that need to be considered and catered for in any new development, pushing the boundaries yet further. In addition, customer base oil requirements are also evolving, and these also need to be factored into any fit-for-purpose testing program. Many of the required industrial gear oil performance attributes have competing needs and thus the target area for a successful formulation is continually reducing in size. A selection of the key challenges, and approaches taken to address them, will be discussed.

9:00 am – 9:30 am

3811282: Investigations on the Pitting Resistance and Efficiency of Gears with Very Smooth Surfaces

Adrian Sorg, Thomas Tobie, Karsten Stahl, Technical University Munich, Garching b. München, Germany; Dominik Kratzer, Klueber Lubrication Muenchen GmbH & Co KG, Munich, Germany

The flank load carrying capacity and efficiency of gears depend strongly on the lubrication conditions in the contact zone of the meshing gears. In this publication, extensive investigations were carried out on case-hardened gears from different grinding processes resulting in low surface roughness and thus beneficial operating conditions. Experimental tests in the FZG standard back-to-back test rig using an ISO VG 100 lubricant with those gears show that fine tooth flank surfaces increase the pitting load carrying capacity. Random sample tests with lubricants from practical application indicate the transferability of the results to practical conditions. Recommendations are developed to allow an optimization of existing load carrying capacity calculations within ISO 6336. Furthermore, efficiency tests at different operating conditions not only show the influence of surface roughness but also of the grinding process itself.

9:30 am – 10:00 am

3812296: Method for Characterization of Wear Behavior of Steel-Bronze Rolling-Sliding Contacts Relating to Worm Gears

Philipp Schnetzer, Technical University of Munich, Garching bei München, Germany

Worm gears are usually used in industrial applications with the material pairing of hard worm and softer worm wheel, where the failure type wear often limits the service life. Up to now, extensive, costly, and time-consuming component wear tests need to be carried out for each tribological pairing in order to predict the amount of wear on worm gears. For this reason, this presentation covers a new method to characterize the wear behavior of steel-bronze rolling-sliding contacts regarding worm gears. Therefore, tribological conditions for a model contact tested on a two-disk test rig derived from a worm gear tooth contact will be presented. Based on this, a method for gravimetric wear determination will be explained. Further, the wear behavior for a steel-bronze pairing will be characterized on the model contact. Special focus is given to similar trends in wear behavior observed between worm gear and two-disk tests and this with significantly shorter test run times of the new method.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3810716: AI-Based Prognostic and Health Management in Wind Power Drives

Lisa Binanzer, Martin Dazer, Andreas Nicola, University of Stuttgart, Stuttgart, Germany

Gear failure caused by pitting is one of the leading reasons of downtime in wind turbines. An adaptive operating strategy applies a load reduction of a damaged tooth by the means of torque variation to increase the remaining useful life. For the highest possible increase of service life, condition monitoring data is used to implement an AI-based prognostic and health management strategy. Measurement data from several gears with different degrees of pitting are recorded with a test gearbox. The labeled data are used to train intelligent neural networks for automatic pitting detection during operation. By using reinforcement learning and artificial intelligence it is possible to identify the degree of pitting and the time of occurrence. Different approaches and methods are investigated. Based on this, an intelligent control can be implemented. In summary, the integration of AI in the control of wind power drives enables the increase of the remaining useful life.

11:00 am – 11:30 am

3815106: Catastrophic Failure of Gears in a Tube Mill

Arturo Cardenas, GIGATEC, San Luis Potosi, SLP, Mexico

Gears have played a vital role in the industry since the very beginning. And nowadays, a failure can mean significant disruption to the production lines. Gears are almost always subjected to very high overloads and pressures, making precision and lubrication key factors in preserving reliability. Also, in some cases, gears work under large amounts of metal-forming coolant, which means water contamination. In the same way, bearings are under the same conditions as gears, and both suffer from the effects of the EHL friction losses in the line of contact. In this case, we have a 300 HP tube mill with a catastrophic failure just one month after the user decided to switch to the oil supplier. This paper discusses the failure mode of the gearset and determines the root cause of such failure and how the new oil might (or might not) contribute to the damage.

11:30 am – 12:00 pm

3852012: Development of an Industrial Gearbox Relevant Micropitting Test

Marc Ingram, Thomas Baldwin, Ingram Tribology Ltd., Carmarthen, United Kingdom; Matthew Smeeth, Clive Hamer, PCS Instruments, London, United Kingdom

Micropitting is a type of surface fatigue mechanism where small pits are formed on the surface of gears. The formation of pits leads to a loss of material and a change of geometry on the surface of the gear tooth. This can cause macropits to form and ultimately failure of the part. In this paper we describe the development of a new micropitting test to evaluate the ability of lubricants to prevent micropitting. A three ring on roller test machine is used to investigate the mechanism of micropitting on case carburized 16MnCr5 parts. Different test conditions are investigated by varying the test lambda ratio (film thickness to surface roughness ratio) along with the direction and extent of sliding between the test parts. The roughness of the samples is monitored throughout the test, to balance mild wear, which has been shown to be a competing mechanism to micropitting. The test method is qualified using both simple additive blends and fully formulated oils.

Session 3H | 103C

Commercial Marketing Forum III

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:30 am

3909481: Oil Filtration Systems – Clean Oil is the Lifeblood of your Turbine System

Tom Lisy, Clark Reliance/Oil Filtration Systems, Strongsville, OH

Turbine lubrication oil & EDC fluids become contaminated with solids and water through normal use. Removal of moisture/water (free, emulsified, dissolved); nondeformable particles (grit, debris, wear metals); polar compounds of oxidation/varnish; and entrained gasses will extend equipment life. Controlling contamination recues unscheduled downtime. Oil Filtration Systems provides purification through vacuum dehydration, adsorptive media, and barrier filtration. We will discuss the selection criteria for removal of the most common and troublesome contaminants. Oil purification techniques and system placement considerations will be outlined.

8:30 am – 9:00 am

3929565: Biosynthetic Technologies – Estolides – High Performance Sustainable Base Oils for Lubricant and Metalworking Formulations

Matt Kriech, Biosynthetic Technologies, Indianapolis, IN

Biosynthetic Technologies delivers innovations for a sustainable future. As such, we offer products that are bio-based and readily biodegradable yet also deliver superior performance characteristics. In this session, we will discuss our expanding product line of sustainable base oils which are made from derivatized organic fatty acids. These oils provide excellent hydrolytic stability, oxidative stability, seal compatibility as well as other superior performance characteristics. This 30-minute session will be a must for anyone looking to develop a high performance EAL product line.

9 – 9:30 am

3908121: LANXESS – Sulfur Carrier EP Additive Portfolio-EP Additive Trends in MWF Formulations

Holger Sudmeyer, LANXESS, Cologne, Germany

The most commonly used EP additives in metalworking applications are sulfur carriers. LANXESS developed their first light colored sulfurized ester already in 1957 and the portfolio has evolved since then to meet modern requirements. Sulfur Carriers available today, cover a broad range of sulfur content, molecular size, reactivity, and polarity. They can be versatilely used to reduce friction and to prevent adhesive and abrasive wear in boundary and mixed lubrication. They perfectly comply with the increasing demand for light colored, low odor metalworking oils, higher machining speeds and temperatures and increasing requirements for sustainable products with a favorable ecological and toxicologic profile. This presentation starts with an introduction into sulfur carrier EP additives and major trends in the industry. It will then provide an overview of the solutions that LANXESS as a major producer of EP components has in its portfolio to meet future requirements and growing demand.

9:30 am – 10:00 am

3831329: King Industries – Introducing KX460 – A High Performance Water-Based Rust Preventive Additive for Formulations Demanding Superior Metal Parts Protection in Severe Corrosion Conditions

Clifford Pratt, King Industries, Inc., Norwalk, CT

Protection of metal parts against corrosion, including everything from small to large components, remains a critical element in the financial investment of parts manufacturing. Given the shift driven by environmental regulation from the market dominant oil-solvent based rust preventives to water-based formulations, a gap has emerged in products that provide adequate protection. KX460 is a rust preventive additive intended for use in water-based systems with superior performance in high humidity and salt containing atmospheres. Through a series of ASTM, DIN, and in-house tests, KX460 has demonstrated exceptional corrosion protection performance in addition to emulsion stability under stressed conditions. KX460 for water-based rust preventives combines performance, stability, and versatility expected in traditional RP systems without the concerns of handling volatile solvents.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3910535: Eastman Synergex™ Multifunctional Amine Additives for Metalworking Fluids

Robert Ash, Eastman, Kingsport, TX

Eastman has been selling Synergex™ for many years. This presentation will focus on specific products in the Synergex family, including Synergex™ LA, Synergex™ T and the newly reintroduced Synergex™ T Plus. All are unique, high-quality alkyl alkanolamines that meet a variety of metalworking fluid needs. Synergex™ T is a low-odor tertiary amine that can replace DIPA in many formulations. Synergex™ LA is a hydrophobic tertiary amine with similar physical properties to DCHA and is particularly useful in soluble and semisynthetic oils. It can be used along with Amietol M12 (MDEA) to make a competitively priced but high-performing fluid. Synergex™ T Plus has been reintroduced to meet market needs such as extended fluid life and emulsification.

3H

11:00 am – 11:30 am

3908077: Introducing Lubrizol's® EcoAssurant™ Industrial Environmentally Acceptable Lubricant (EAL) Portfolio Featuring the New IG22EL Series of Industrial Gear Fluids

Joshua Dickstein, The Lubrizol Corporation, Wickliffe, OH

Environmental protection is a top priority for many companies around the world. Growing demand for lubricants with improved environmental protective properties is driven by regulatory requirements and social responsibility. Environmentally Acceptable Lubricants (EALs) describes lubricants that demonstrate the ability to meet regulatory standards for biodegradability, nonbioaccumulative potential and minimal toxicity to aquatic life. Lubrizol launched the newly branded EcoAssurant™ portfolio of finished fluids, additive packages and components that play a vital role in elevating the environmentally protective qualities of lubricants in industrial applications, worldwide. This presentation will explain the move towards EALs and the opportunities for lubricant manufacturers. The presentation will introduce the latest addition to the EcoAssurant™ portfolio, Lubrizol® IG22EL series of industrial gear fluids, formulated from bio-based synthetic esters, meeting the EU Ecolabel requirements.

11:30 am – 12:00 pm

3909620: Münzing – FOAM BAN® Defoamers for Tank Side use in Aqueous Metalworking Fluids

Stefanie Velez, Münzing Chemie GmbH, Bloomfield, NJ

While using metalworking fluids in the field, foam can be unavoidable due to long term shear, contamination, and other environmental factors, therefore, tank side defoamers are required in many applications. FOAM BAN® tank side defoamers are, ready to use and formulated to provide various levels of foam control and knockdown. The effectiveness of different defoamer types, including non-Si, low-cost, and highly persistent 3D-Siloxane based defoamers will be shown along with how these defoamers perform in fully synthetic, semisynthetic, and soluble oil metalworking fluids. In addition, the optimal method to handle and add tank side defoamers will be discussed based on the theoretical framework of foam generation and stabilization.

Session 3I | 104A

Electric Vehicles III

Session Chair: Greg Hansen, Southwest Research Institute, San Antonio, TX

Session Vice Chair: Cole Frazier, Southwest Research Institute, San Antonio, TX

8:00 am – 8:30 am

3808007: High Temperature Lightweight Al-Alloys for EV Regenerative Brake Rotors

Tomas Grejtak, Amit Shyam, Janet Meier, James Haynes, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN; Peter Blau, Blau Tribology Consulting, Enka, NC

The next generation electric powertrain brakes require light weight, good resistance to wear, corrosion, creep, and heat, and high thermal conductivity. As an attempt to replace the traditional cast iron, this study investigated the feasibility of using advanced aluminum alloys for electric vehicle (EV) braking rotors. ORNL recently invented high-temperature Al-Cu-Mn-Zr (ACMZ) alloys with excellent microstructural and mechanical stability beyond 300 °C. Two versions of the ACMZ alloys with 6 and 9 wt% Cu, respectively, were tested on a sub-scale brake tester against a commercial brake lining material. Analysis was done based on combination of frictional, wear, and temperature responses, which are among the key factors for candidate brake rotor materials.

8:30 am – 9:00 am

3818885: High-Pressure Fuel Pump Performance with Low Lubricity Fuels Monitored with Acoustic Emission Technology

Nikhil Murthy, Vincent Coburn, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

The high-pressure fuel pump (HPFPs) contained in many diesel engine fuel delivery systems is heavily impacted by the lubricity of the fuel. As newer synthetic fuels and biofuels become introduced into the market these concerns become more pronounced. In this study we seek to understand the effect of fuel viscosity and chemistry on performance and durability of HPFPs. A HPFP was operated with two low-viscosity (1 cSt) fuel components, ethanol and decane. Post-failure analysis was conducted to determine the extent of damage and root cause of failure. Additionally, acoustic emission sensors were used as an exploratory non-destructive method for early fault detection. A combination of position correlation and frequency analysis was used to identify the initiation of damage in the pumps.

9:00 am – 9:30 am

3834898: Impact of High Speed of Rolling Element Bearings in Oil Lubricated Contacts

Farrukh Qureshi, The Lubrizol Corporation, Wickcliffe, OH; Azzedine Dadouche, Rami Kerrouche, National Research Council, Ottawa, Ontario, Canada

The transition from internal combustion engine- (ICE) powered vehicles to electric motor-powered vehicles is fundamentally changing lubricant requirements. Due to torque-speed characteristics of electric motor, the drivetrain is mechanically simpler. The input speeds for drivetrain components are much higher compared to conventional ICE driven transmissions. As a result, lubricating high speed bearings and gears becomes a challenge. Improved test capability for mechanical components is needed for evaluation and further development of lubricant/mechanical systems. This work attempts to develop knowledge on high-speed behavior of rolling element bearings under high-speed conditions. The results from this study indicate that high-speed bearing operation would result in significant temperature increase and may also cause skidding/sliding of rolling components leading to reduced life of such components.

9:30 am – 10:00 am

3810703: A Novel Method of EV-Fluid Differentiation in Compatibility with Enameled-Insulated Copper Wires

Annabelle Minz-Schuett, Minz Pruef + Test GmbH, Limburg, Germany; Joerg Fahl, Volkswagen AG, Wolfsburg, Germany

Hairpin technology is leading the way in the construction of highly efficient electrical motors for electrified mobility. A powerful and efficient e-motor requires a coating of the copper wires with sufficient surface strength. Special attention must be paid to the insulation varnish regarding its compatibility with the surrounding lubrication oil / EV-fluid. In this context, an industry-wide demand for suitable material combinations of heat and lubricant resistance lacquer as well as compatible EV-fluid formulations is rapidly increasing. Inventing a method for qualifying suitable lacquer and fluid formulations was essential. The Volkswagen AG succeeded in developing a novel, very precise and quick method for the differentiation of specially designed EV-fluids in compatibility with insulation varnish formulations. This paper gives an insight on this project based on testing coated rectangular wires and the change in their mechanical properties.

10:00 am – 10:30 am – Break

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3I

10:30 am – 11:00 am

3848344: Multi-Physics and Multi-Scale Prediction of Tribological Behavior of Electric Powertrain

Mahdi Mohammadpour, Loughborough University, Loughborough, United Kingdom

The tribology of automotive powertrains is facing significant changes in the range of working conditions including speeds and loads and consequently the applicable failure modes and lubrication regimes. This is due to rapid development of electrification in this industry, introducing novel landscape for this subject. To facilitate informed and objective design decisions at this demanding transitional stage, detailed and accurate methodologies are required. This may ultimately lead to ambitions vision of zero-prototype development. To achieve this goal, realistic prediction tools are required. This necessitates multi-physics method involving tribology, dynamics, and electromagnetics. The method should embed a multi-scale approach to consider detailed physics-based phenomena at surface level which is the origin of tribological behavior. In this paper, a multi-physics and multi-scale method is proposed for realistic predictions of modern electrified powertrains.

11:00 am – 11:30 am

3829359: Performance Evaluation of Greases for Electric Vehicle Motors

Gabriel Calderon Salmeron, Sergei Glavatskih, KTH Royal Institute of Technology, Stockholm, Sweden; Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden

The electrification of the automobile industry demands high efficiency from all the electric vehicle (EV) systems and subsystems. Grease lubrication is one of these systems. However, measuring the grease lubrication frictional levels under EV conditions requires novel methods that represent accurately these conditions. Our previous publication [1] presented an experimental setup to measure frictional torque in grease-lubricated bearings. In this work, we expand this investigation in our high-speed bearing test rig, capable of measuring bearing friction and self-induced temperature, by evaluating Lithium, Polyurea and Polypropylene greases in closer EV motor conditions. 12 experiments of 28 days each were performed under an interesting range of variable and fluctuating speeds. The impact on sustainability was quantified by measuring the energy consumption for each of the grease candidates, providing an important insight into future experimentation with greases of EVs.

11:30 am – 12:00 pm

3811805: Ultrasonic Measurement of Interference Pressures for a Planetary Gear Shaft-Bush Contact

Gary Nicholas, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom; Hiroyuki Suzuki, Hino Motors Ltd., Tokyo, Japan

Planetary gearboxes are widely utilized in industry due to their high torque-to-weight ratio, compactness, low operating noise. The carrier within these gearboxes consists of shafts which are interference fitted into the carrier. Excessive contact pressure from the interference fit, high operational loading as well as microscopic sliding causes severe wear at these contact interfaces. This has been attributed to geometrical errors and operational loading of the shaft. As such, it was desirable to conduct a quantitative assessment of the pressures experienced at the carrier-shaft interface. In this work, ultrasonic waves generated using focused probes were used to measure the interference pressure of various steel shaft-sleeve specimens. The ultrasonic responses were initially calibrated using specimens of known interference pressures. Contact pressure measurements were subsequently carried out on two shaft-sleeve specimens designed to be representative of the shaft-carrier contact.

Session 3K | 201A

Metalworking Fluids III

Session Chair: Alexes Morgan, Sea-Land Chemical Company, Westlake, OH

Session Vice Chair: Stephanie Cole, Münzing North America, LP, Mount Holly NC

8:00 am – 8:30 am

3809212: Environmental Advantages of Sulfur-Containing EP Additives in Metalworking Processes

Wilhelm Rehbein, Thomas Klein, LANXESS Deutschland GmbH, Mannheim, Germany

Sulfur carriers are well known as EP additives and for a long time have been successfully used in many types of metalworking fluids. They can be beneficially used in almost all kind of metalworking processes to prevent adhesive wear under boundary and mixed lubrication conditions. Compared to chlorinated paraffins, the frictional forces in certain metalworking processes are more than 25% lower by using suitable sulfur carriers. However, in addition to their superior protection against cold welding, sulfur carriers show many benefits in terms of toxicity, environmental impact and energy efficiency when compared to other EP additives. Many sulfur carriers are e.g. manufactured by sulfurization of natural, renewable raw materials like vegetable oils. The presentation will explain how sulfur carriers reduce the environmental footprint of metalworking fluids while maintaining or even increasing their performance and support the metalworking industry on their way to a more sustainable future.

8:30 am – 9:00 am

3834082: How To Design A Sustainable Metalworking Fluid Formulation Using Renewable Base Fluids

Jesse Ziobro, Univar Solutions, Houston, TX; Stephanie Cole, Münzing North America, LP Mount Holly, NC

The increasing interest in sustainable chemistry technology and biobased fluids are becoming more sought after than traditional petroleum-based lubricants. This paper dives into the three pillars of sustainability: economic, environmental, and social while defining what this means for a metalworking fluid formulation. For the economic pillar, the performance of the formulated metalworking fluid will be evaluated against standards. To address the environmental pillar, this paper will investigate several renewable resources in place of nonrenewable resources. This presentation will show the design of experiments to formulate several water-dilutable metalworking fluids containing ingredients from renewable resources, and the testing associated with metalworking fluids to show performance characteristics.

9:00 am – 9:30 am

3812454: Pick a PAG, Any PAG: Selecting Polyalkylene Glycols for Synthetic Coolants

Zach Magness, Calvary Industries, Fairfield, OH

Polyalkylene glycols (PAGs) form the classic lubricity base for synthetic metalworking coolants. These materials come in a wide variety of solubilities, molecular weights, starter molecules and final structures. With so many options, why choose one material over another? This paper will compare final coolant properties when using different PAGs including foam and lubricity.

9:30 am – 10:00 am

3815117: Total Rehab of a Metalforming Fluid System in a Tube Mill Machine

Arturo Cardenas, Oltec, San Luis, SLP, Mexico

When the pandemic arrived in America, the industry in Mexico decided to stop their plants for at least one to two months (March-April 2020) to try to break the contagious chain. This meant leaving some deposits of metalworking fluids unattended, allowing the growth of every kind of microorganism (bacteria, fungi, yeasts, lichens, etc.). After that, when the industry tried to come back to work, they had to deal with this enormous problem considering that the low production levels did not allow them to invest in a fresh charge. After a year of working in such conditions, they finally decided to plan the changing of the fluids, but at that moment, the problem had become catastrophic. In this paper, we will analyze how atypical factors can severely impact metalworking fluids and then affect the production levels in the industry and how they were remedied. Also, we will briefly discuss best practices to preserve this kind of system in the best conditions.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3811678: Development of a Benchtop Tribological Test to Emulate Metal Cutting

Syed Ashir Sajid, Rob Dwyer-Joyce, University of Sheffield, Sheffield, South Yorkshire, United Kingdom; Christopher Taylor, Advanced Manufacturing Research Center, Sheffield, United Kingdom; Thawhid Khan, Manchester Metropolitan University, Manchester, United Kingdom

On route to commercialization, metalworking fluids (MWFs) are subjected to extensive testing regimes consisting of tribological bench tests and full-scale production tests. Despite this, current tribological bench tests in industry provide a weak correlation with real machining processes. As a result, MWF manufacturers are often forced to rely on costly validation trials when determining fluid performance. In response, this study aims to develop a novel, tribological, benchtop test that can emulate metal cutting, serving to establish the impact of varying MWF compositions for stainless steel, mild steel & aluminum. In doing so, a research methodology is developed which seeks to bridge the gap between tribological bench testing and machining processes. The methodology provides a fluid performance indicator that will allow companies to carry out cost-effective tests to give instant results and to understand how the MWF technology behaves in a fundamental aspect to accelerate product development further.

11:00 am – 11:30 am

3834110: Boundary Lubricant Additive Response Comparisons Between Aluminum and Copper Alloys Using Twist Compression Tests (TCT)

Ted McClure, Sea-Land Chemical Company/SLC Testing Services, Westlake, OH; Alexes Morgan, Sea-Land Chemical Company, Westlake, OH

Electric vehicles (EV) require changes in the way vehicles are manufactured, the metalworking fluids used, as well as lubricants used in operation. Electric current and heat management are important considerations, involving copper and aluminum. Aluminum content of continues to increase in auto body structures for lightweighting purposes. The Twist Compression Test (TCT) is a bench test that creates lubricant starvation under high pressures and sliding contact. It is used to evaluate the boundary lubrication performance of lubricants and galling resistance of material couples. This presentation is an extension of work presented at STLE in 2022. TCT is used to evaluate a series of boundary additives on automotive body aluminum and copper. Additive responses with the two metals will be compared. Boundary additives evaluated include polymers, esters, and fatty acids, alcohols, and amines. The aim is to provide useful data for formulation.

11:30 am – 12:00 pm

3812650: The Aminolysis and Hydrolysis of Esters in Water-Dilutable Metalworking Fluids

Karl Zhong, Quaker Houghton, Wayne, PA

Esters are affective boundary lubricants in metal working fluids (MWFs) and function to reduce tool wear and improve the surface quality of machined parts. However, esters in MWFs tend to undergo chemical reactions over time. These reactions may adversely affect the performance of a MWF – particularly in terms of lubricity, emulsion stability, foam tendency and product shelf life. The predominant reactions of esters in water dilutable MWFs are aminolysis and hydrolysis. In this study, we investigated aminolysis and hydrolysis of esters in a typical water dilutable MWF. The aminolysis and hydrolysis reactions were monitored by respective changes in the product's alkalinity and acidity. In addition to this kinetic information, the effect that aminolysis and hydrolysis have on each ester's lubricity, emulsion stability, and foam tendency were also investigated.

Session 3N | 202B

Nanotribology III

Session Chair: Mehmet Baykara, University of California, Merced, Merced, CA

Session Vice Chair: TBD

8:00 am – 9:00 am

Invited Talk

3832034: Superlubricity – Toward Design of Zero-Friction and Zero-Wear Materials

Diana Berman, University of North Texas, Denton, TX

In this presentation, we overview recent advances in establishing the fundamental understanding of materials interactions at sliding interfaces and use this knowledge as a guide to developing nanomaterials solutions that enhance reliability and efficiency of tribological systems. We evaluate tribological performance of nanostructured materials, including combinations of various 2D materials, and demonstrate realization of superlubricity regime at macroscale. To extend the lifetime of the tribological materials, we demonstrate tribochemically driven self-replenishment of materials inside the contact interfaces, thus enabling a zero-wear sliding regime. Overall, the findings have not only allowed us to solve some long-standing puzzles but could also open a new avenue for the development of new concepts and design strategies for next generation of tribologically efficient materials systems.

9:00 am – 9:30 am

3811864: Speed Dependence of Friction in the Structural Superlubricity Regime

Wai Oo, Mehmet Baykara, University of California, Merced, Merced, CA

Structural superlubricity constitutes an intriguing, intrinsic lubrication mechanism for small-scale mechanical systems, whereby incommensurability at the interface results in vanishingly small friction forces. Despite significant research progress in recent years, many open questions remain regarding the physical limitations of this unusual phenomenon. Here, we present experimental results on the speed dependence of friction forces in the structural superlubricity regime. In particular, we perform manipulation experiments on gold nanoislands on

graphite by way of atomic force microscopy. Results point toward a linear increase of friction force with sliding speed instead of the much more common logarithmic dependence, supporting theoretical predictions based on the concept of "thermal drift" [1].

9:30 am – 10:00 am

3811155: Role of Contact Line in Structural Lubricity Breakdown

Hongyu Gao, Universität des Saarlandes, Saarbrücken, Germany

Structural lubricity describes a state of ultra-low friction between two well-defined contact surfaces that are incommensurate so that energy dissipation is systematically annihilated. In the case of manipulating islands at nanometer length-scale, such a low-friction state can be under the influences of, e.g., relative rotational/sliding orientation, island geometry and dimensions. In this report, by means of molecular dynamics, we demonstrate that instabilities can be introduced from quasi-discontinuous dynamics of the Moiré patterns near a propagating contact line while sliding a gold island on a HOPG substrate. Such discontinuity can be attributed to the symmetry breaking nature of a multi-layer gold with its (111) surface parallel to graphite basal plane. The elevated mean fictional forces exhibit only weak dependence on the sliding speed, or namely Coulomb-type friction, according to Prandtl.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3810593: Single-Asperity Sliding Friction Across the Superconducting Phase Transition

Andre Schirmeisen, Dirk Dietzel, Justus-Liebig University, Giessen, Germany; Wen Wang, Southwest Jiaotong University, Chengdu, China

In sliding friction, different energy dissipation channels have been proposed, including phonon and electron systems, plastic deformation, and crack formation. Here, we present friction experiments of a single-asperity sliding on a high-Tc superconductor BSCCO from 40 to 300 kelvin. Overall, friction decreases with temperature as generally expected for nanoscale energy dissipation. However, we also find a large peak around Tc. We model these results by a superposition of phononic and electronic friction, where the electronic energy dissipation vanishes below Tc. In particular, we find that the electronic friction constitutes a constant offset above Tc, which follows a power law in agreement with Bardeen-Cooper-Schrieffer theory. Furthermore, we found a strong influence of step edges on the superconducting friction signal, which is due to different cleavage planes of the BSCCO crystal. This shows that friction on superconductors is extremely sensitive to the atomic surface structure.

11:00 am – 11:30 am

3815745: Investigating Nanotribological Behavior of Graphitic Surfaces in the Binary Mixtures of Hexadecane and Cyclohexane

Prathima Nalam, Thomas Bui, Bhadrakalya Pathirannehelage, Luis Velarde, University at Buffalo, Buffalo, NY; Behnoosh Baboukani, University of California, Berkeley, Berkeley, CA

In this study, we select alkane solvent mixtures of n-hexadecane (linear, in-plane structure) and cyclohexane (aromatic, staggered structure) to tune the structural order of the solvated layers in the vicinity of multilayer graphene and fused silica. Vibrational Sum Frequency Generation (vSFG) measurements show n-hexadecane chains undergo a transition from a slight-tilt configuration at lower concentrations (<40 wt.% in cyclohexane) to flat-lying molecules as the concentration of hexadecane was increased. By measuring the changes in gauche defects and surface coverage by hexadecane at the interface in solvent mixtures, higher alkane ordering, and adsorption-free energies were observed on multilayer graphene compared to the silica surface. A similar transition in friction measurements, i.e., at 40 wt.% hexadecane in cyclohexane, was measured using a single-asperity atomic force microscope probe on graphitic surfaces, indicating a direct influence of structural order on friction.

11:30 am – 12:00 pm

3834279: Connecting Interfacial Structure and Friction for Graphene-Based Interfaces

Li Yuan, Daniel Sanchez, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Ashlie Martini, University of California, Merced, Merced, CA; Suzhi Li, Xi'an Jiaotong University, Xi'an, China; Graham Cross, Trinity College Dublin, Dublin, Ireland

Interfacial structure significantly affects the frictional behavior of graphene. We endeavor to connect atomic-scale interfacial characteristics with graphene's frictional behavior. First, we perform molecular dynamics simulations of friction for a Si tip sliding on substrate-supported graphene. Different graphene/substrate interfacial atomic registries are obtained by varying the substrate surface roughness. Rougher substrates allow better registry, decreasing tip/graphene friction. As well, local substrate roughness affects tip-graphene friction, rivaling the known strengthening effect associated with graphene's layer-dependent friction. We also experimentally study the crystallographic orientations of graphene pleats formed by the self-folding of graphene. Interfacial commensurability is determined by lattice-resolved lateral force images. This highlights how interfacial organization strongly affects friction in graphene-based systems.

Session 4A | 101A

Lubrication Fundamentals IV: Polymers

Session Chair: Fakhrul Hasan Bhuiyan, University of California, Merced, Merced, CA

Session Vice Chair: Brendan Miller, Chevron Oronite Company, Richmond, CA

2:00 pm – 2:30 pm

3810988: Same Engine, Less CO_2 – Lubricant Solutions to Maximize Fuel Economy without Compromising Oil Consumption

Seemann Michael, Phil Hutchinson, Thomas Schimmel, Sabrina Strube, Evonik Specialty Chemicals, Singapore, Singapore; Ellington JoRuetta, Evonik Oil Additives USA, Inc., Horsham, PA

Improving fuel efficiency is a major goal of the automotive industry. A common approach to improve fuel economy is the adoption of lower viscosity engine oils, however this approach raises durability concerns and may require engine re-design. A new approach is to increase the Noack evaporation loss limit combined with advanced viscosity index improvers like comb polymers. Studies demonstrate that a 0W-20 engine oil at 21% Noack can even deliver higher FE than a 0W-16 oil. Increased Noack volatility might raise concerns of higher oil consumption. Therefore, Evonik investigated oil consumption in a state-of-the-art engine using a broad test matrix including multiple Noack volatilities, SAE viscosity grades, and base stocks. All parameters showed poor correlation with engine oil consumption, suggesting that Noack volatility is a poor indicator of oil consumption. This new approach allows maximized fuel efficiency within the same SAE grade through optimized viscometric performance.

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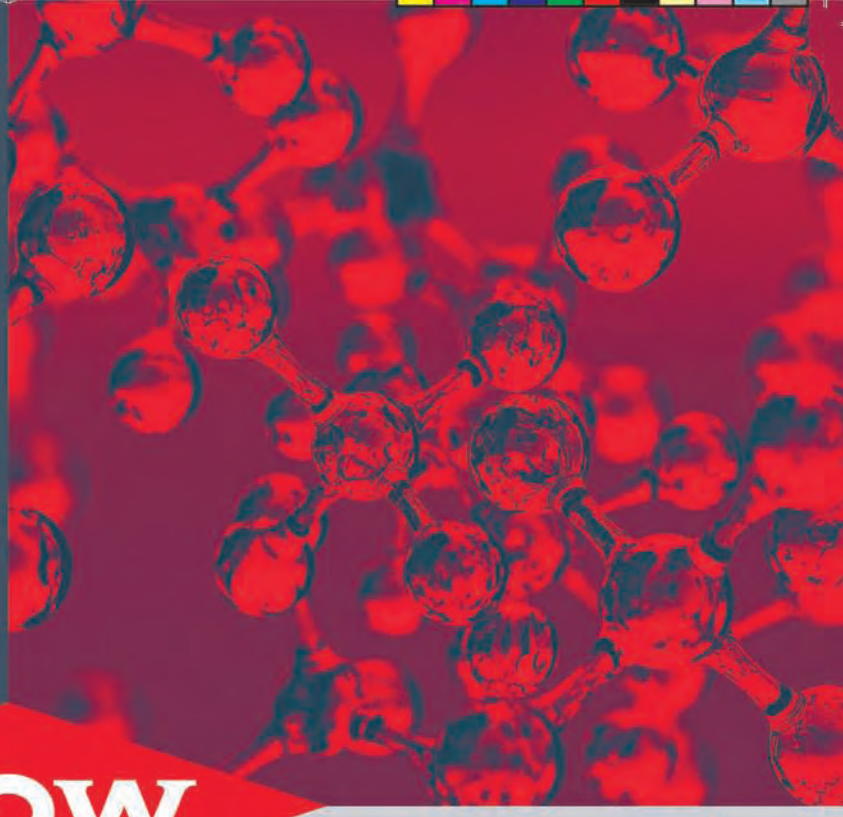

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4A

2:30 pm – 3:00 pm

3832539: Dual Functional Additives: Polymer Adsorption and Boundary Effects

Amran Mohamed, Janet Wong, Imperial College London, London, United Kingdom; Sarah Matthews, Shell Global Solutions (UK) Ltd., London, United Kingdom

Due to increasing environmental concerns, there is a growing need towards multi-functional additives in lubricant formulations. Polymeric additives, due to their flexible molecular design, are good candidates for multi-functional additives. While they are commonly used as viscosity modifiers, they may also adsorb on surfaces and provide boundary lubrication, i.e., act as friction modifiers. This dual functionality is controlled via modifications of the polymer's chemistry and architecture. In this study, using dissipative particle dynamics (DPD) simulations, along with quartz crystal microbalance (QCM) to provide experimental validation, the impact of polymer adsorption on the shear behavior of the polymer solution is investigated. In our QCM experiments we find that the block copolymers, which aggregate in bulk, can adsorb onto the metal surface to form a viscous layer. Through modelling we investigate this viscous layer, and the implications of this on the solution's shear response.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3829833: Low Temperature Viscometrics and PPD Effect on Group III Base Oils

Jacob Scherger, Functional Products Inc., Macedonia, OH

Pour Point Depressants (PPDs) are designed to improve low temperature performance [1], and picking the right PPD for the right application is crucial to maintaining low temperature fluidity to prevent lubricant starvation and part damage as well as to increase efficiency during low temperature start and operation. Here several different PPD chemistries as well as different wax affinities within the same chemistry have been screened for their effectiveness in a variety of API Group III base oils. Both pour point and dynamic viscosity were used as metrics of comparison. It was found that being tuned to a specific wax profile is more important than specific PPD chemistry, and there can be significant differences in an oil's PPD response even amongst the same API group. Further, the reliability of pour point testing as a screen for low temperature viscosity was evaluated.

4:30 pm – 5:00 pm

3833360: Viscoelasticity of Lubricants with Polymer Additives Sheared in Nanogaps and Their Temperature Dependence

Shintaro Itoh, Takumi Nozue, Kenji Fukuzawa, Naoki Azuma, Hedong Zhang, Nagoya University, Nagoya, Japan

Lubricant viscosity is becoming lower to improve the fuel efficiency of automobiles. As lubricant viscosity decreases, the load capacity becomes smaller, resulting in narrower sliding gaps, leading to wear and seizure. Therefore, developing low-friction technology in boundary lubrication conditions while achieving low-viscosity lubricants is an urgent issue. A previous study reported that adding polymers to lubricating oil reduces friction in boundary lubrication conditions. The authors successfully measured the shear viscoelasticity of lubricants with a polymer additive by shearing it in a nanogap. The results showed that the adsorption layer of polymers has a significant effect on the nanogap. Specifically, the viscosity index increased compared to the bulk state, and a mechanical response suggestive of rubber elasticity was detected. The results of this study provide fundamental insight into the molecular design of polymer additives and the understanding of lubrication phenomena.

5:00 pm – 5:30 pm

3832683: Effect of Polarity of Polymer Additives on Their Adsorption and Boundary Film Formation

Yuxi Song, Kenji Fukuzawa, Shintaro Itoh, Naoki Azuma, Hedong Zhang, Nagoya University, Nagoya, Japan; Tomoko Hirayama, Naoki Yamashita, Kyoto University, Kyoto, Japan

Blending oil-soluble polymer additives into lubricant base oils has been employed as an effective way to improve boundary lubrication performance. In this study, we directly measured the thickness and the gap during sliding of nanometer-thick adsorbed polymer films using vertical-objective-type ellipsometric microscopy (VEM) and neutron reflectometry. The structure and boundary film formation ability of adsorbed films formed by polyalkylmethacrylate (PAMA) polymers with different polarities were investigated. It was found that with the increase in the polarity of the polymers, more loosely adsorbed chains (loops and tails) in the adsorbed films were found. These loosely adsorbed chains temporarily trapped free polymer chains flowing into the gap between sliding surfaces, resulting in a thicker boundary film.

5:30 pm – 6:00 pm

Lubrication Fundamentals Business Meeting

Session 4B | 101B

Rolling Element Bearings IV

Session Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

Session Vice Chair: Kushagra Singh, Purdue University, West Lafayette, IN

2:00 pm – 2:30 pm

3801800: Atomistic Investigation of White Etching Bands Transformations in Rolling Element Bearings

Mostafa El Laithy, Ling Wang, Terry Harvey, nCATS, Southampton, United Kingdom; Bernd Vierneusel, Schaeffler Technologies AG & Co KG, Schweinfurt, Germany

Rolling contact fatigue-induced microstructural transformations in bearing steels like dark etching region (DER) and white etching bands (WEBs) results from complex rearrangement processes at the atomic level. Detailed insights into the material structure recently resulted in a unified mechanism, showing that these features develop due to cyclic energy build-up and release processes leading to the formation of ferrite grains and lenticular carbides. Now, further analysis on the WEBs using transmission electron microscopy and atomic probe tomography has revealed that the bands consist mainly of equiaxed ferrite grains, while lenticular carbides are associated with elongated ferrite grains. The analysis shows carbon segregating at equiaxed grain boundaries, and carbon migration from these boundaries is observed during grain rotation/coalescence. These results are further important contributions to a deeper understanding of the mechanisms involved in the formation of DERs and WEBs.

2:30 pm – 3:00 pm

3811078: Initiation and Drivers of Butterfly and White Etching Area Manifestation In Bearing Steels

Mostafa El Laithy, nCATS, Southampton, United Kingdom; Ling Wang, Terry Harvey, University of Southampton, Southampton, Hampshire, United Kingdom; Alexander Schwedt, Joachim Mayer, RWTH Aachen University, Aachen, Germany; Wolfram Kruhoeffer, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

Butterflies and white etching cracks (WECs) have been commonly linked with RCF premature failure in bearings within various applications. Butterflies typically develop around stress raisers such as non-metallic inclusions (NMIs) and voids, where wings of white etching areas (WEAs) initiate at the interface between the inclusion and the steel matrix. It has been suggested that manifesting of butterflies is one of the formation mechanisms of WEC. Despite the large number of studies on butterflies decades ago, their formation mechanisms and the links between butterflies and WEC remain unclear. This study investigates the development of butterflies formed in roller bearings under a range of stress conditions. The initial results have shown that shear stress has a significant influence on the formation frequency of butterflies but can limit their further growth. Also, inclusion type, such as sulphides, oxides and duplex inclusions, has been found to influence the formation of butterflies.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3830596: Thermal Simulation of Bearing Components in Customer Applications

Travis Shive, Fabrizio Mandrile, SKF USA Inc., Lansdale, PA

Bearing temperatures are a direct influence of bearing operating clearance or preload. The relationship of temperature from inner ring, through rolling element, to outer ring is the driver for the forementioned clearance or preload. Traditionally the temperature relationships are defined at a pre-selected value having the rolling elements halfway between the inner and outer ring temperature for most cases. Since this isn't always the proper condition, software advancements allow the simulation of bearing component temperatures. This would include inner ring, rolling elements and outer ring. Software for simulating bearing temperature can account for various system configurations and mating components surrounding the bearings. This understanding of bearing temperatures in various applications and designs provides ability to optimize bearing design and improve performance.

4:30 pm – 5:00 pm

3832888: Comparison of Thermal Characteristics of an Aero-Engine Cylindrical Roller Bearings: All-Steel Versus Hybrid

Rami Kerrouche, Azzedine Dadouche, National Research Council, Ottawa, Ontario, Canada; Salah Boukraa, University of Blida, Blida, Algeria

Modern aircraft engines must meet rigorous requirements, such as thrust to weight ratio, efficiency, and environment protection. These requirements affect all engine modules and components, including rolling-element bearings. The latter must withstand extreme operating conditions because of the high thermal impact due to elevated rotational speeds and loads. In this study, a series of experimental measurements were carried out under realistic operating conditions of load, speed and oil flow rate to investigate and compare thermal characteristics of two of cylindrical roller bearings: an all-steel (M50/M50-Nil) and a hybrid roller bearing. The latter features silicon nitride (Si_3N_4) rollers. A high-speed bearing rig was used to conduct the experiments. An array of twelve thermocouples, equally distributed around the circumference of the outer ring, was used to measure the thermal profile within the bearing. Oil supply and drain temperatures were also measured during the rig tests.

5:00 pm – 5:30 pm

3808858: Simulation of Temperature Distribution in Rolling Bearings

Hannes Grillenberger, Philipp Rödel, Yunsheng Huang, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

The temperature and heat generation in rolling element bearings are important criteria of these machine elements, especially in context of sustainability and energy saving. However thermal calculations during the design process are usually not done, as the typical state of the art is based on finite element or transient calculations which could produce high quality results but take long time and high computer power. Additionally, the thermal characteristics of the rotating rolling contact are hard to represent in these methods. However, the need for accurate thermal characteristics of a bearing is high to optimize the system. The presentation will present a new method that returns the temperature distribution inside a bearing as well as the heat transfer according to thermal boundary conditions and frictional energy. As it is based on quasi-static calculations and is for steady state results only, it converges quickly and can be used for optimizations and handled by a large user group.

5:30 pm – 6:00 pm

3834108: Investigation of Heat Generation in Ball Bearings for Liquid Rocket Engine Turbopumps

Hiromitsu Kakudo, Satoshi Takada, Japan Aerospace Exploration Agency, Kakuda-shi, Japan

Ball bearings supporting the main shaft of rocket engine turbopumps which supply cryogenic propellants to the main combustion chamber are critical elements of a rocket vehicle. Inside a turbopump, a portion of propellant is circulated to cool ball bearings that are self-lubricating ones using polytetrafluoroethylene as a lubricant. Heat generation of ball bearings rises the coolant temperature which affects its density and mass flow rate. Therefore, it is important to predict the heat generation precisely. In this research, heat generation in turbopump bearings is measured and compared with one theoretically predicted on a numerical model.

6:00 pm – 6:30 pm

Rolling Element Bearings Business Meeting

Session 4C | 102A

Fluid Film Bearings II

Session Chair: Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA

Session Vice Chair: Cori Watson-Assa, GE Aerospace, Cincinnati, OH

2:00 pm – 2:30 pm

3830467: Nonlinear Dynamics of an Accelerating Rotor Supported on Self-Acting Air Journal Bearings

Manas Pattnayak, Jayanta Dutt, Raj Pandey, Indian Institute of Technology Delhi, Delhi, India

Self-acting air bearings are used in several high-speed micro-turbomachines, where frequent acceleration/deceleration of the rotor is common. The whirl amplitude of the rotor must be kept within tolerable limits for safe operations of the system. This research presents, for the very first time, the dynamics of an accelerating rotor supported on self-acting air journal bearings. Due to the rotor unbalance, the dynamics between the translational and spin coordinates get nonlinearly coupled. The work utilizes these coupled equations to plan appropriate acceleration schedules to limit the whirl amplitude and frequency as low as possible. Based on the research, it is found that in the presence of rotor unbalance, the acceleration should be scheduled in at least three regimes: the first with the maximum torque, the second with the minimum torque, and the last with an intermediate torque.

2:30 pm – 3:00 pm

3829137: Observation of Polymer Chain Deformation in Oil Under High Shear

Tatsuya Kusumoto, Moritsugu Kasai, Idemitsu Kosan Co.,Ltd., Ichihara-Shi, Japan; Mikihito Takenaka, Kyoto University, Institute for Chemical Research, Kyoto, Japan

Fluid resistance and oil film formation on the lubrication surface in engine oil are important issues in improving engine oil performance. However, the viscosity measurement of the engine oil with polymer is insufficient to clarify the fluid resistance and oil film formation. We thus made a novel cell that enables us to measure the polymer orientation under high shear rates by using small-angle X-ray scattering (SAXS). We have succeeded in visualizing the orientation process of polymer molecules under high shear rates by using the cell with synchrotron SAXS at SPring-8, Japan.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3833882: On the Experimental Performance of Additively Manufactured Hybrid Fluid Film Bearings

Keun Ryu, Junwon Heo, Minsoo Wee, Yeseul Kim, Jihan Kim, Hyunsung Jung, Homin Lim, Hanyang University, Ansan, Gyeonggi-do, Republic of Korea

New types of hybrid (hydrostatic plus hydrodynamic) fluid film journal and thrust bearings are designed and fabricated using direct metal laser melting (DMLM) technology with Inconel 718. The bearings include unique features combining multiple feeding holes or porous layers on the bearing surfaces and compliance of each pad structure. Static and dynamic load characteristics of the test journal and thrust bearings are measured using various test fluids (air, cold and hot water, and cryogenic liquid nitrogen) at various rotor speeds, supply pressures, and static/dynamic load conditions. The reliable performance of the additively manufactured hybrid fluid film bearings offers a remarkable opportunity to be implemented in future high-performance turbomachinery.

4:30 pm – 5:00 pm

3833660: Multi-Objective Taguchi-Grey Relational Analysis of Bearing Parameters on the Steady-State Performance of Three-Lobe Journal Bearing Lubricated with Non-Newtonian Fluid and Operating with Slip/No-Slip Conditions

Amar Ambekar, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India

Multilobe bearings have potentially enhanced the system's stability due to multiple converging regions formed by their unique geometry. The slip length and power law index of the non-Newtonian lubricant are critically important in the design of journal bearings. Taguchi-Grey relational-based optimization techniques are used in the current research to find the optimal combination of parameters such as preload factor, slip length, and power law index to optimize the steady-state performance characteristics of three-lobe journal bearings. The approach considers three levels of slip length, a power-law index, and preload factor. According to the numerical analysis, the preload factor has the most significant effect on side leakage, accounting for approximately 86% of the total influence of independent parameters on steady-state characteristics. The power law index has a 77% influence, while slip has a 45% and 48% influence on non-dimensional load and friction variable, respectively.

5:00 pm – 5:30 pm

3834094: A Directed-Lubrication Thrust Bearing Solution for High-Speed and/or High-Load Applications

Bruce Fabijonas, Richard Rodzwic, Kingsbury, Inc., Philadelphia, PA

We present recent results of the performance of a directed-lubrication thrust bearing being investigated at Kingsbury, Inc. The design has been effective in cooling thrust bearings at high speeds and high loads on the test rig. Unlike other directed-lubrication bearings, the design goal is to allow for oil flow rates greater than those typical of a directed-lubrication bearing with a focus on cooling the bearing and meeting the customer's operating conditions. We compare the performance results on the test rig against a flooded design and another directed-lubrication design. Finally, we discuss the results of CFD simulations of the bearings to understand the behavior of heat dissipation within each bearing type.

5:30 pm – 6:00 pm

Fluid Film Bearings Business Meeting

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Session 4D | 102B

Materials Tribology IV

Session Chair: Mark Sidebottom, Miami University, Oxford, OH

Session Vice Chair: TBD

Session Starts at 4:00 pm

4:00 pm – 4:30 pm

3811709: Comparing the Performance of Molded Versus Machined High-Performance Plastics in Unlubricated Friction and Wear Environments

Tanner Alauzen, Allegheny Performance Plastics, Pittsburgh, PA

Plastic prototype parts can save money, save time, and demonstrate part functionality. In the automotive sector, plastic parts are injection molded due to high annual volumes. To avoid long lead times of producing prototype molds, engineers consider machined prototypes for design validation. In friction and wear environments, engineers commonly avoid choosing plastic machined parts to validate design functionality. Engineers neglect machined parts over injection molded parts due to the different plastic manufacturing methods and additives being exposed due to the machining process. Two high performance plastics will be used to evaluate the difference between molded and machined parts. Factors such as overall part performance, wear rate, coefficient of friction, temperature, and surface finish will be evaluated. This study will aim to determine if there are significant differences between molded and machined plastic parts in friction and wear environments.

4:30 pm – 5:00 pm

3831322: Tribological Study of Oil-lubricated Thick Polydopamine + Polytetrafluoroethylene + Cu Nanoparticle Coatings

Sujan Ghosh, Min Zou, David Huitink, Hayden Carlton, Charles Miller, University of Arkansas, Fayetteville, AR; Samuel Beckford, German Perez, SurfTec, Fayetteville, AR

The tribological performance of oil-lubricated thick polydopamine (PDA) + polytetrafluoroethylene (PTFE) + Cu nanoparticle (NP) coatings and the effect of Cu NPs on the coating thermal conductivity were studied. Three aqueous PDA + PTFE + Cu NPs solutions were sprayed on cast iron containing 0.12, 0.25, and 0.50 wt.% of Cu NPs, respectively. The samples were annealed using a 3-step heating process and compacted to about 45 µm thickness using a hot press during the last heating step. Adding 0.25 and 0.50 wt.% Cu NPs improved the coating durability in oil by 52% and 33%, respectively. The improved durability was attributed to the better mechanical properties, stronger coating adhesion, and more thorough cross-linking of PDA and PTFE facilitated by the Cu NPs. In addition, adding Cu NPs also improved the coating thermal conductivity, with the PDA + PTFE + 0.25wt.%Cu coating showing a 12% improvement.

5:00 pm – 5:30 pm

3832482: Mechanistic Understanding of Substrate Roughness Effect and Coating Cohesion on the Scratch Resistance of Polytetrafluoroethylene-Based Thin Coatings

Charles Miller, Min Zou, University of Arkansas, Fayetteville, AR

Combining nanoindenter scratches and scanning electron microscopy of the scratches, a mechanistic understanding of the effect of substrate roughness on the scratch resistance of polytetrafluoroethylene (PTFE) thin coatings without and with graphite particles was obtained. The mechanical interlocking of the coating and substrate roughness was crucial for reducing tensile stresses in the coating that lead to tearing and global delamination. Furthermore, incorporating graphite particles improved the coating cohesion and coating compaction. The combined effects of substrate roughness and graphite particles in the PTFE layer enabled the coatings to endure high contact pressure nanoindenter scratches. This behavior shows promise for applying these solid lubricant coatings to bearing and gear applications in demanding conditions.

Session 4F | 103A

Environmentally Friendly Fluids III

Session Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

Session Vice Chair: Daniel Garbark, Battelle Memorial Institute, Columbus, OH

Session Starts at 2:30 pm

2:30 pm – 3:00 pm

3817741: Tribological Performance in High-Pressure Carbon Dioxide Environment for Compressor Application

Ayesha Asif, Ahmad Amiri, Andreas Polycarpou, Texas A&M University, College Station, TX

Since the early-mid 2000s, there has been a renewed interest in environmentally friendly refrigerants with reduced or zero global warming potential. While there have been significant advances with HFO 1234yf, CO_2 as a refrigerant, (R744) is still the most widely abundant and inexpensive refrigerant. The initial challenges remain of operating under much higher pressures including supercritical conditions. In supercritical phase, CO_2 can exhibit a low viscosity and high density but pressurizing beyond the critical point (31.1°C, 1081 psi) is challenging. In this study, we revisit the lubricity of CO_2 refrigerants under newly formulated POE (polyolester) and PAG (polyalkylene glycol) lubricants. Additionally, the effect of lubricant was combined with various friction and wear-reducing polymer coatings. The best tribo-pairs were evaluated based on the impact of using lubricant oils in combination with the coatings under different CO_2 environments.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3831911: Novel Green Friction Modifiers for Aqueous Lubricants

Sam Davison, Joseph Lanigan, University of Sheffield, Sheffield, United Kingdom

It is estimated that 50% of all the lubricants produced today are lost into the environment. Novel, green lubricants are a necessary technology to protect the environment for future generations while simultaneously demonstrating excellent lubricity with the potential to reduce frictional energy losses. Oil based lubricants can be biodegradable, some of which are very well established. Water based (or aqueous) lubricant systems are being explored as an alternative, especially in maritime applications. Poor mixed-lubrication performance especially at bearing start-up holds back aqueous and water-based lubricants when compared to oils. Friction modifiers are part of the key to this current tribological challenge to facilitate a shift away from (carbon intensive) oil lubricated systems with effective, more environmentally friendly additives. Unique friction modifiers and viscosity index improvers are available for experimental testing with friction and wear assessment.

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4F

4:30 pm – 5:00 pm

3833026: Investigating the Effect of Novel Processing Routes in Enhancing the Tribological Behavior of 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

Due to renewability, biodegradability, good viscosity and non-toxicity, soybean oil is being used as lubricating oil in various sectors. The purpose of this research is to formulate lubrication oil using soybean oil which will be used for next generation automotive, aerospace and UAV sectors. In this study, raw soybean oil was additized with phosphonium cation-based ILs and characterized using FTIR and NMR spectroscopy. Oxidation and mass stability were analyzed using a pressure differential scanning calorimeter (PDSC) and thermogravimetric analysis (TGA), respectively. The tribological behavior of raw and modified soybean oils was investigated with silicon nitride ball and AISI 52100 steel flat under high frequency on ball and flat reciprocating sliding machine from ambient temperature to 1000C. The wear tracks were evaluated using the surface profilometry, and SEM-EDS analysis to reveal the wear mechanisms under different lubricated conditions.

5:00 pm – 5:30 pm

Environmentally Friendly Fluids Business Meeting

Session 4G | 103B

Gears II

Session Chair: Nikhil Murthy, DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Session Vice Chair: Pinzhi Liu, ExxonMobil Research and Engineering, Annandale, NJ

2:00 pm – 2:30 pm

3831228: Industrial Gear Efficiency Demonstration

Andrew Gant, Afton Chemical Ltd., Bracknell, Berkshire, United Kingdom

This work aimed to bring in-house full-scale instrumented gearbox efficiency measurement capability and to establish the main determinants of efficiency in terms of both gearbox operating characteristics and fluid componentry. Discrete project stages can be summarized as: MTM Stribeck curve trend identification as per lubricant base oil and additive pack and identifying operating regimes in the full size gearbox which produce the greatest lubricant discriminability; examination of the deconvolution of specific additive pack chemistries in synthetic base oils and synthetic PAO constituents in terms of boundary, mixed and full EHL lubrication regimes; and identify correlations of gearbox mechanical power losses with the lubricants' pressure-viscosity coefficients.

2:30 pm – 3:00 pm

3833949: Performance Enhancement of Plastic Gears – The Potential of Laminated Woven-Carbon-Fiber Einforced Plastics

Damijan Zorko, Zoran Bergant, Borut Cerne, University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia

Laminated composites have so far received little attention as a potential material for gear transmissions. In the study, the potential of autoclave cured woven carbon fiber reinforced plastic (CFRP) composite gears was investigated by a combination of experimental and numerical methods. Test gears were milled from a high-quality, autoclave cured, woven carbon fiber reinforced epoxy composite plate, and tested in mesh with a steel pinion on a gear testing rig. The employed methods enabled the identification of the composite's mechanical, thermal, and tribological characteristics, as related to the studied gear pair application. Failure mechanisms were studied by employing a scanning electron microscope and a high-resolution optical microscope. A novel FEM-based iterative procedure is proposed, which enables an implicit evaluation of the material pair's coefficient of friction. CFRP gears exhibited a significantly improved performance in comparison with the plastic and composite gears.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

Gears Business Meeting

Session 4H | 103C

Commercial Marketing Forum IV

Session Chair: TBD

Session Vice Chair: TBD

2:00 pm – 2:30 pm

3906317: VBASE® Oil Company – Secondary Polyol Esters™ – Novel Sustainable Group V Base Oils

Martin Greaves, Jeff Dimaio, Zach Hunt, VBASE Oil Company, Baar, Switzerland

VBASE® Oil Company has developed and commercialized a new family of sustainable synthetic base oils for lubricant applications which offer formulators a solution to developing lubricants that meet the highest technical performance standards and modern environmental accreditation requirements. The Secondary Polyol Esters™ (SPE) have been 'Designed for Sustainability' by linking building blocks that have high levels of biodegradability to create novel base oils of a wide range of viscosities. The versatility of this chemistry allows hybrid structures to be developed for use as base oils in industrial, marine, and automotive applications. This presentation will introduce the VBASE® Oil Company and highlight some of the unique properties of SPEs, their environmental accreditations and the applications they serve. A look into the future of base oils that are in the development pipeline will also be shared.

2:30 pm – 3:00 pm

3905547: Evonik Oil Additives – Win with Efficiency and Formulation Flexibility – Lubricant Solutions to Maximize Fuel Economy without Compromising Oil Consumption

Matt Hauschild, Sabrina Strube, Seemann Michael, Evonik Oil Additives, Horsham, PA

The engine oil market is evolving towards ultra-low viscosity grades as OEMs seek to meet ever-tightening fuel economy target mandates. Key automotive regions are promoting ultra-low viscosity engine oils, with different Noack volatility levels. Higher Noack levels support the formulation of fuel economy oils by allowing an optimized combination of advanced viscosity index improvers and lower viscosity base oils. For some, this approach may trigger concerns of increased oil consumption. To assess this impact, Evonik used a state-of-the-art engine to test a matrix of engine oils including multiple Noack volatilities, SAE viscosity grades, and base stocks. This study demonstrated that oil consumption is independent from all investigated oil parameters. Modern engine oils may be formulated to higher Noack levels enabling more formulation

flexibility and maximizing fuel efficiency within the same SAE grade through optimized viscometric performance without compromising oil consumption.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3908768: Kao Chemicals – Solutions for Today's Metalworking and Cleaning Formulations

Sabine Wohlfahrt, Kao Chemicals Europe, Emmerich, Germany

KAO Chemicals is a well-established global supplier of surfactant technology used in high-end technical applications such as metalworking and specialty cleaning. Our surfactant range covers emulsifiers (AMIDET and KAO FINDET MB/AKYPO ROX®), co-emulsifiers (AKYPO® and FOSFODET) and solubilizers (AKYPO® LF) used as key ingredients for cutting edge metalworking and cleaning formulations. The additive toolbox was designed based on the demanding needs of the industry. It is offering solutions for low foaming, multifunctional fluids with improved corrosion protection, stability, and cleaning performance. Our products are cornerstones for sustainable formulation due to their efficiency, multifunctionality and the extension of the overall fluid longevity. We are pleased to share our surfactant technology and competencies with metalworking and cleaning formulators in times of shrinking additive options.

4:30 pm – 5:00 pm

3909337: ExxonMobil – Peak Performance, More Fuel Economy Savings with SpectrasSyn™ in the Automotive Lubricant Space

Manish Patel, ExxonMobil Chemical Company, Spring, TX

The automotive industry is developing new driveline technologies, like hybrid and fully electric vehicles (EV), to help OEMs and formulators meet their global emission targets. This will require the development of next generation lubricants. These products must be compatible to the new set of conditions, such as the electric environment and higher operating speeds, while at the same time providing enhanced durability and improved energy efficiency. Therefore, novel SpectaSyn™ MaX 3.5 has been introduced leveraging the low-viscosity/low-volatility (LVLV) PAO technology platform, allowing lubricant manufacturers to develop their next generation lubricants. This presentation will examine the key attributes of SpectaSyn™ MaX 3.5 and will showcase how automotive lubricant manufacturers can increase formulation flexibility to develop their next generation products for emerging applications, building on synthetic basestock, LVLV PAO technology.

5:00 pm – 5:30 pm

3908157: BASF Corporation – New Offerings and Developments in BASF Lubricant Antioxidant Technology

Kevin DeSantis, Daniel Niedzwiecki, BASF Corporation, Florham Park, NJ

To support our customers in their lubricant development, BASF has expanded its lubricant antioxidant offering to include several new aminic and phenolic antioxidants. Antioxidants have been used in lubricants for much of the past half century. They are accepted as a standard lubricant component in the market due to their impact on both fluid performance and life. With our extensive and trusted portfolio of IRGANOX® antioxidants, BASF has long been a leading provider of antioxidant technology. The global trend in enhanced oxidation control in both industrial and automotive applications is driven by the need for improved machine efficiencies, longer service life and higher temperature stability. These challenging performance needs along with an ever-changing regulatory landscape require new specialty antioxidants. This presentation details the new commercial and experimental products BASF offers to tackle the challenges of today and tomorrow.

5:30 pm – 6:00 pm

3909999: Italmatch Chemicals – Streamlining Metalworking Fluid Development: A Package System for Success

William Harwood, Italmatch SC, LLC, Cleveland, OH

Developing a water-based metalworking fluid is a time-consuming process that requires the development team to consider raw material costs and availability, environmental regulations, performance testing and more. To address this challenge, Italmatch has developed a package system with the latest technologies that can significantly reduce development time while providing the latest technology advancements for your metalworking fluid needs, from semi-synthetic to synthetic applications. This novel approach has been field-tested and proven to provide reliable performance. The flexible system allows for personalization of the final product, providing a solution that is both efficient and tailored to the customer's needs.

Session 4I | 104A

Electric Vehicles IV

Session Chair: Cole Frazier, Southwest Research Institute, San Antonio, TX

Session Vice Chair: Thomas Wellmann, FEV North America, Auburn Hills, MI

2:00 pm – 2:30 pm

3834255: Oil Aeration: Findings for Testing in High Speed, Low Volume Systems

Ricardo Hein, Conexo Inc., Acworth, GA

Oil aeration is one of the key stressors for fluids in systems operating at high speed and with low volumes. An aeration tester was introduced back in 2018 uses high agitation to secure a constant free air content in the fluid and it measures he aeration characteristics in fluids. A lot of effort has been dedicated to developing a valid and replicable aeration testing method. Recent development of this aeration testing system now allows for understanding the relations between aeration level in the fluids and the variables speed, volume, and temperature. The latest findings were performed to correlate to innovative mechanical designs such as are used in electrification. These findings include studies with variable temperature, with different volumes of fluid, and with different speeds. The testing apparatus and methods are described. This system opens the possibilities in testing the aeration characteristic of not just different fluids, engine oils, transmission, and hydraulic fluids.

2:30 pm – 3:00 pm

3833698: Flammability and Combustibility of Oils in the Presence of High Voltages

Paul Shiller, FirstPower Group LLC, Twinsburg, OH

The electrification of vehicles adds an interaction that needs to be addressed. Having combustible and flammable materials in close proximity to high voltage is inherently dangerous. Not only for the materials used in the functioning of the vehicle but also other materials; cleaners, spray lubricants, and others used in the upkeep and maintenance of the vehicle. This presentation will discuss how flammability is measured and defined with respect to a flame and in the presence of an electrical spark. Both liquids and aerosols will be covered. High voltages sometimes lead to a condition of partial discharge.

Partial discharge is where an electrical discharge does not completely bridge a gap. This can happen when insulation is damaged, or a conductive path develops. When partial discharge occurs and is submerged in oils it can lead to decomposition producing methane, hydrogen, acetylene, and other materials to track the health of the system.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3852434: Rheological Test Methods for E-Lubricants

Carlos Sanchez, Southwest Research Institute, San Antonio, TX

The move towards E-mobility presents new challenges in designing materials and lubricants to interact efficiently in a mechanical-electrical system. 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. Previous studies at SwRI have demonstrated that an electric field affects the viscosity of new and used driveline fluids in different ways. Using a similar approach, other lubricant properties were investigated while subjected to an electric field. This work will discuss current rheological test methods used for evaluating greases and driveline fluids, and new methodologies being developed to meet the demands of electrification.

4:30 pm – 5:00 pm

3813679: Test Development for Copper Corrosion in E-Fluids

Gwenaelle Philibert, Jiayi Liu, Shell, Houston, TX; Christopher Dobrowolski, Shell Global Solutions, Hamburg, Germany

The electrical windings in electric motors are predominantly manufactured from copper which provides impressive levels of electrical conductance, thermal conductivity and ductility at reasonable cost. Typically, the windings are electrically insulated using a thin coating of varnish and are vulnerable to electrical breakdown if the varnish degrades. As motor power densities have increased, the need for active cooling of the windings has risen, leading to the development of wet motors in which transmission lubricants are deliberately brought into contact with the windings to facilitate heat removal. Adverse interactions between the fluid and the varnish can precipitate electrical breakdown stimulating the development of protective oil performance specifications by many of the world's OEMs. Here, we report on the development of an analytical test capable of screening and comparing the copper corrosion performance of candidate lubricants.

5:00 pm – 5:30 pm

3831841: Monitoring of Electrode Degradation Within Lithium-Ion Batteries During Prolonged Use

Daniel Williams, University of Sheffield, Sheffield, United Kingdom

The move to renewable energy sources requires the storage of said energy to meet current and future demands. The use of batteries as a storage method demands the increase in energy and power density, along with the longevity of the cells to reliably provide to our needs. Lithium-ion chemistries are the most prevalent battery technology, but are prone to degradation over time. A measurement system to monitor the degradation of the electrodes within lithium-ion cells non-destructively has been developed. Ultrasonic transducers were installed to the casing of a 2000mAh pouch Li-polymer cell. The transducers would emit ultrasonic pulses that would travel through the cell, recording information about the internal layers. As the battery degrades, the change in the signal response would be recorded and used to characterize the degradation. The variation in cell degradation over different charge rates will be explored.

5:30 pm – 6:00 pm

3833906: Efficiency and Range Determination Aspects for Fluid Development of Battery Electric Vehicles

Thomas Wellmann, FEV North America, Auburn Hills, MI

The use of innovative drivetrain technologies of fully electrified propulsion systems is expected to play an increasingly important role in helping OEMs meet the future fleet CO_2 reduction targets. One important aspect for battery electric vehicles is the driving range on a single battery charge. It is desirable to increase range by optimizing the driveline and overall vehicle efficiency without sacrificing comfort and performance. This presentation will showcase key drivetrain components, how their efficiency and performance can be evaluated via simulation and testing. Methods for fluid evaluations on component level will be highlighted. Further, vehicle level testing for range determination will be described and details that can influence fluid selection will be highlighted. Examples from testing and simulation will be utilized to describe energy flow in various vehicle systems. The importance of fluids for lubrication and cooling on the overall vehicle energy management will be shared.

Session 4K | 201A

Metalworking Fluids IV

Session Chair: Jennifer Lunn, Reminderville, OH

Session Vice Chair: Bridget Dubbert, Engineered Lubricants, Company, Maryland Heights, MO

2:00 pm – 2:30 pm

3815325: Assessing the Functional Lubricity of MWFs by an Innovative Tool

Ameneh Schneider, Optimol Instruments, München, Germany

The compositions of MWFS must be developed constantly due to stringent occupational, health and environmental regulations, but without losing performance. Investigation on energy efficiency, coolant effect, lifetime of tools and finally the optimization of the concentration of active ingredients in the formulation are the subjects for more investigations. The innovative set up in SRV under unidirectional sliding helps to assess the functional and tribological performances of newly developed MWFs in a laboratory by using small amounts of fluid and test parameters based on various application field experiences. A large test matrix with different tool/work material combinations and fluid compositions was selected and performed. Optimization of test parameters for each material is necessary and will be discussed. The reproducible results of tribological performances (friction and wear) and temperature evolution during tests enabled a good ranking among the tested MWFs.

2:30 pm – 3:00 pm

3819234: Performance Testing of Sulfur-Based Estolides in a Full Metalworking Fluid Formulation with Comparison of Other Commercialized Sulfur-Based Additives

Marlon Lutz, Biosynthetic Technologies, Indianapolis, IN

At Biosynthetic Technologies (BT), we aim to develop innovative high performing molecules in a sustainable fashion. Sulfur-based additives are one of the leading wear preventative additives to prolong machine life and performance. There has been a decline in the development of sulfur-based additives both conventional and bio-based, and with the movement to phase out chlorinated paraffins, this warrants the need to prepare and evaluate novel bio-based sulfur additives for the metal-working industry. BT has developed novel bio-based estolides with sulfur

embedded and have successfully formulated into full water dilutable metalworking fluid formulations and evaluated anti-wear properties in comparison to other formulations that contained commercial sulfur-based additives. Performance testing of sulfur-based estolides will be discussed and these results show that sulfur-based estolides do deliver competitive anti-wear properties compared to commercially available sulfur-based additives.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3829851: Post Machine Cleaning – How to Pick the Right Surfactant for the Job

Ashley Milton, Clariant Corporation, Mount Holly, NC

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

4:30 pm – 5:00 pm

3833803: Synergy of Polymeric Esters in Synthetic Metalforming Fluids

Andrew Yoder, The Lubrizol Corporation, Wickliffe, OH

Polymeric esters have shown to provide excellent lubricity in synthetic metalworking fluids particularly stamping and drawing fluids. These esters have been shown to be equal to or better than traditional glycol-based or block copolymer-based lubricants without the inverse solubility associated with them. However, polymeric esters are not without their own drawbacks. This research will show that by combining two different esters, they provided better overall performance than each individually and matched or outperformed traditional polyglycol based chemistries. Data will also show a further synergistic effect when this combination is used with extreme pressure and/or anti-wear additives.

5:00 pm – 5:30 pm

3833542: Polyglykol as Performance Wear Lubricant and Synergism with EP Additives on Net Oil Metalworking Fluid: Part 2

Eduardo Lima, Dow Chemical Brazil, Jundiai, Brazil

Effective additive development against wear is required to create more robust scientific information on earlier studies that considers known factors that affect wear, which brings negative aspects on the metalworking process, potential damages on metal parts, unwanted wear on relatively expensive tools, or inability to create adequate and precise measures on metal parts. It is possible to avoid the negative effects of metal-to-metal contact by incorporating the right chemicals that provide a barrier between surfaces, either through physical adsorption or even chemical reaction. This study presents performance results examining more from the Oil Soluble Polyglycol as Synthetic Performance Wear Lubricant Additive proposal and covering more on synergism with Typical EP Additives Study on Typical Net Oil Metalworking Fluid, creating relation between additive molecular weight relation, bubbles release, and performance results.

5:30 pm – 6:00 pm

3830588: Next Generation Multi-Metal Wire Drawing Fluids

Kathleen Havelka, Denis Buffiere, Amelie Bretonnet, Harish Potnis, ANGUS Chemical Company, Buffalo Grove, IL

Vehicle electrification and growing energy consumption are driving demand for improved copper and aluminum wire drawing fluids. Wire drawing is a difficult operation requiring fluid formulations to provide several important characteristics. This presentation demonstrates the use of specialty amino alcohols in wire drawing fluids improve fluid performance and longevity, enabling formulators to develop high performing fluids with improved sustainability profile. In this study, wire drawing fluids developed using amino alcohols exhibit excellent lubricity, good cleanliness, and low foaming with extended fluid life. The structure-property relationships of the amino alcohols are explored highlighting unique functionalities formulators can leverage to develop fluids that produce defect-free wires, use less energy and generate less waste. These amino alcohols offer potential in developing next generation fluids that help lower cost, reduce environmental impact, and increase productivity.

6:00 pm – 6:30 pm

Metalworking Fluids Business Meeting

Session 4L | 201B

Tribochemistry I

Session Chair: Faysal Haque, Miami University, Oxford, OH

Session Vice Chair: Ines Blatter, IAM-ZM, Karlsruhe Institute of Technology, Karlsruhe, Baden-Württemberg, Germany

2:00 pm – 2:30 pm

3829853: Synergistic Effects of Antifriction and Antiwear Additives on the Tribological Behavior of Lubricants Derived from Plastic Wastes Under Boundary Lubrication

Pushkar Deshpande, Seungjoo Lee, Ali Erdemir, Texas A&M University, College Station, TX; Ryan Hackler, Massimiliano Delferro, Argonne National Laboratory, Lemont, IL; Yiyu Wang, Ranjan Behera, Wenyu Huang, Aaron Sadow, Iowa State University, Ames, IA

Plastic waste pollution is one of the most pressing issues around the world. Therefore, there is an urgent need for recycling or upcycling them for a green and circular economy. In this study, we investigate the tribological behavior of lubricating oils derived from upcycled plastics (LOUPs) with and without MoDTC and ZDDP in comparison to base oils. These LOUPs were previously studied as neat oils and they provided improved friction and wear properties. LOUP blends were prepared with specific concentrations of antiwear (ZDDP) antifriction (MoDTC) additives. To investigate their synergistic effects, tribotests were performed under boundary lubrication. Results confirmed that these additives are fully compatible with LOUP and can provide significant friction and wear reduction. To understand the tribochemical mechanisms involved, we used analytical techniques such as raman and x-ray photoelectron spectroscopies that confirmed formation of highly protective and slick boundary films.

2:30 pm – 3:00 pm

3809257: Synergistic Interactions Between Bio-based Oleate Ester and Low-Concentration ZDDP Under Reciprocating Contacts

Ju Shu, Cayetano Conesa, Mitjan Kalin, Ardian Morina, University of Leeds, Leeds, United Kingdom

To probe the potential of using bio-based materials as boundary lubricating additives for low SAPS lubricants, ethyl oleate, readily obtained from bio-based resource was investigated under reciprocating contacts in terms of tribological performance. Several surface analyzing techniques including SEM, AFM, synchrotron XAS and ToF-SIMS were then utilized to study the worn surface. A synergy on tribological performance has been observed when the ethyl oleate has been used together with low concentrations of ZDDP showing both lower friction and wear loss, compared to only ethyl oleate or ZDDP as additive with the same total concentration. Based on analyses, we propose a mechanism where ZDDP provides essential resource to the tribo-film composed of glassy zinc polyphosphate to mitigate wear loss and ethyl oleate alleviates shear strength to facilitate the formation of zinc polyphosphate and homogenises tribo-film distribution.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 4:30 pm

3833824: Mechanochemistry Study of ZDDP Antiwear Additives

Lu Fang, Robert Carpick, Martin Webster, University of Pennsylvania, Philadelphia, PA; Spyridon Korres, ExxonMobil, Hamburg, Germany

Recent experiments in the elastohydrodynamic lubrication regime revealed zinc dialkyldithiophosphate tribofilm is driven via shear stress. However, those experiments neglect the inhomogeneous stress distribution. We present a new approach, contact strip analysis method (CSAM), accounts for and takes advantage of the stress variation. In CSAM, the contact is discretized into multiple strip-shaped sub-areas for kinetic analysis. Compared to current methods, CSAM provides better spatial precision, and more efficiency to study mechanochemistry with fewer experiments. The data followed stress-assisted thermal activation (SATA), permitting measurement of activation energies and volumes for tribofilm growth. We also used atomic force microscope to investigate tribofilm growth in the boundary regime. Three growth stages were observed: slow linear growth, fast linear growth, and then fast removal. The first two follow SATA. The mechanisms behind the multiple growth stages will be discussed.

4:30 pm – 5:00 pm

3830539: Influence of the Organic Moiety on the Tribological Properties of MoS_2: Glycol Hybrid Nanoparticles-Based Dispersions

Fabrice Dassenoy, Jules Galipaud, LTDS/ECL, Ecully, France; Inaki Garcia, Ivet Kosta, Hans Grande, Eva Garcia-Lecina, CIDETEC, San Sebastian, Spain

MoS_2: glycol hybrid nanoparticles were synthetized through a polyol route. Their tribological properties when used as lubricant additives in a PAO6 base oil were investigated using a pin-on-disk tribometer. An important friction reduction and good anti-wear performances were observed compared to the base oil and to the no modified particles. The post-mortem characterization showed that the tribofilm formed on the wear surfaces during the friction test is at the origin of the excellent tribological performance of the MoS_2 nanoparticles. In particular, it was demonstrated that the interaction of MoS_2 with the organic moiety of the nanoparticles plays a key role in the friction reduction and the good anti-wear properties of the dispersions.

5:00 pm – 5:30 pm

3811302: The Influence of Slide-Roll Ratio on Glycerol Oleate Tribofilm Formation in the Boundary Lubrication Regime

Marjan Homayoonfard, Ali Ghanbarzadeh, Sven Schroeder, Ardian Morina, University of Leeds, Leeds, United Kingdom; Peter Dowding, Infineum UK Ltd., Abingdon, United Kingdom

Ever tightening environmental and emissions legislation creates demand for lubricant additives with low or no phosphorus and sulphur contents. Many organic friction modifiers fulfil these requirements. However, the mechanisms by which they lower friction and protect surfaces in the boundary lubrication regime are still not fully understood. We have performed tribological studies with steel surfaces of the three glycerol oleate OFMs (including combinations of them). Formulations of glycerol monooleate (GMO), glycerol dioleate and glycerol trioleate in PAO4 base oil were tested at two different temperatures in an MTM-SLIM tribometer as a function of sliding-rolling ratio (SRR),from pure sliding to pure rolling conditions. The thickness of the formed tribofilms was tracked throughout the experiments and their chemical composition was subsequently examined using ToF-SIMS. The correlation between the tribofilm formed, running conditions and the tribological performance will be discussed in detail.

5:30 pm – 6:00 pm

3812998: In Situ Carbon Tribofilm Formation Given by a Novel Organic Friction Modifier

Wei Song, Jinjin Li, Jianbin Luo, Tsinghua University, Beijing, China

Organic friction modifier (OFM) can effectively reduce friction coefficient, especially during boundary lubrication. Usually, the tribological performance of an OFM depends on the interfacial interaction between the tribopair surface and OFM. In this work, a novel OFM without sulfur and phosphorus was synthesized and employed as an additive in PAO. This OFM provides a much lower friction coefficient and wear track width than reported amphiphilic friction modifiers, like oleic acid. Surface analysis including AFM, Raman, FTIR, XPS and TOF-SIMS show that there is a 30~50 nm viscoelastic tribofilm formation on the wear track, and it is mainly composed of graphite carbon. This work reveals a fundamental understanding of OFM mechanism and might guide the novel OFM development.

TLT Meet and Greet

Make sure to stop by the STLE membership booth in the Convention Center foyer across from the Registration Desk and talk to TLT Editor Dr. Selim Erhan and TLT Publisher/ Editor-in-Chief Rachel Fowler on **Sunday, May 21 from 10:00 am – 11:00 am.** They'd love to hear any comments, questions, or suggestions you have about TLT, the official monthly magazine of STLE.

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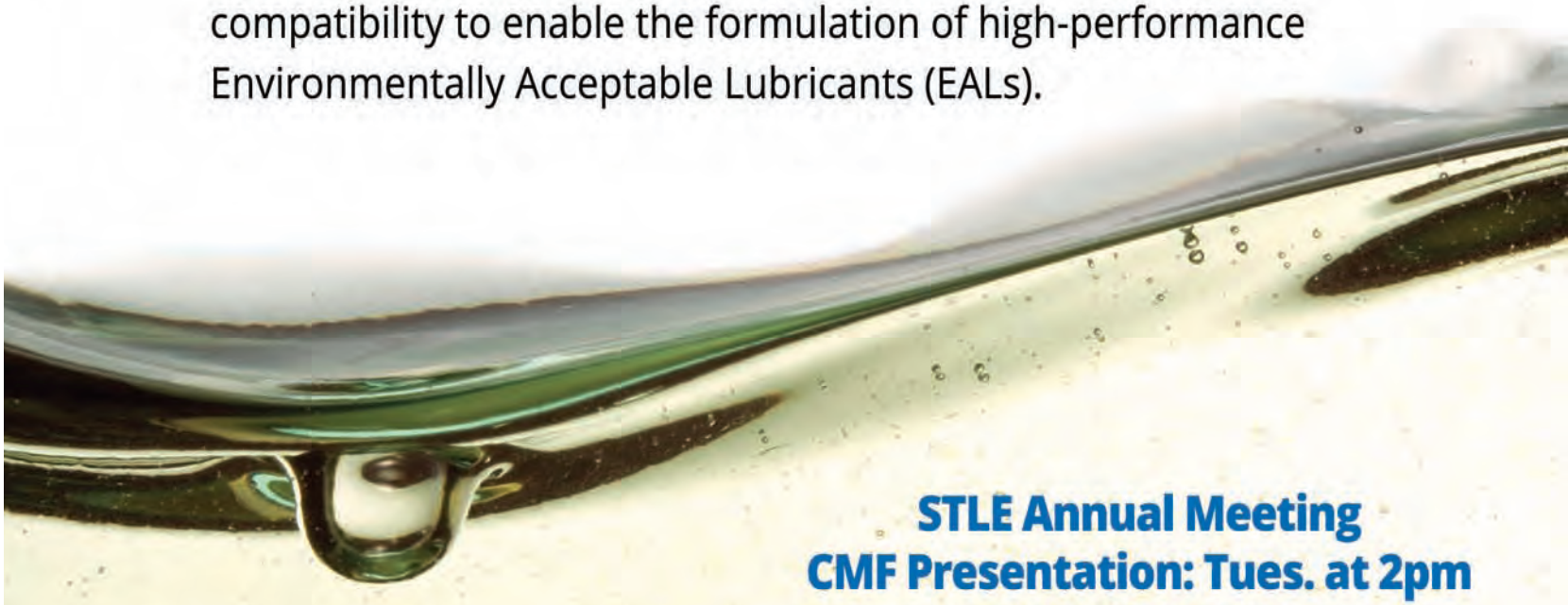

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CMF Presentation: Tues. at 2pm
BOOTH # 726

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Tuesday, May 23 | Technical Sessions

Session 4N | 202B

Nanotribology IV

Session Chair: Diana Berman, University of North Texas, Denton, TX

Session Vice Chair: TBD

2:00 pm – 3:00 pm

Invited Talk

3852275: Molecular Friction Studied by Stereographic Force Spectroscopy

Bizan Balzer, University of Freiburg, Freiburg, Germany

Little is known about how the directionality of an applied force affects the friction behavior at the molecular scale. Atomic force microscopy (AFM) based stereographic force spectroscopy is ideally suited to study the adhesion and friction of single polymers and single bonds under liquid conditions using a combination of vertical and lateral pulling (i.e., angle-dependent pulling) [1]. Here, the directionality of bonds and their influence on adhesion and friction is investigated for covalent bonds, coordination bonds, π-π stacking and receptor-ligand-protein complexes [2,3]. These findings are crucial to understand interfacial interactions for a the bottom-up development of materials with optimized friction properties.

3:00 pm – 4:00 pm – Exhibitor Appreciation Break

4:00 pm – 5:00 pm

Nanotribology Business Meeting

STLE Member Ambassadors …

your connection to the community.

STLE's Annual Meeting welcomes a diverse group of individuals, including long-standing members/attendees, newcomers, and first-time attendees. As an attendee, we encourage you to reach out and connect with our Member Ambassadors, who are fellow industry peers that can help answer general questions about STLE and facilitate introductions to other members of our community, which will provide you an opportunity to network and build relationships. You can connect with these volunteers who will be wearing black **"Member Ambassador"** buttons throughout the week and will also be available at the STLE membership booth in the Convention Center foyer across from the Registration Desk.

Ideation Session

4:00 pm – 6:00 pm

Roundtable Discussion | Grand Ballroom

3832362: Creating the Best Formula on the Planet: An Inventors Perspective and Know How

B.C. Roell, 1st Choice Chemical Consulting, Nelsonville, Ohio

Have you wondered how to break out of the box and create something really special? The secrets of formulating break-through technology will be revealed in this presentation. It begins with a deep understanding of the space your currently working in but more importantly it relies on your experience and knowledge gained from working across products areas. Substitutions of raw materials is not the key to success but a developed understanding of how chemistry impacts on the overall formula. If you've ever been told we've tried that and it can't be done then you will want to see this presentation.

3871801: Big Data in Tribology – A Valuable Resource

N. Garabedian, Karlsruhe Institute of Technology, Karlsruhe, Germany

Linking tribological knowledge across domains has long challenged our community; some cross-domain borders are experimental-computational, industrial-academic, fundamental-applied, existing-new, and nano-macro. The exponential increase of produced and shared data opens the door to a new avenue of approaches that can tackle the aforementioned borders. For example, serially-produced FAIR (Findable, Accessible, Interoperable and Reusable) data could be the key ingredient to enabling tribological results for scalable machine-learning-based analyses, and thus, it can potentially solve tribology's greatest challenges. Unfortunately, applying machine learning and active data management in tribology have been slower to adopt than in other communities. Industrial R&D departments have realized the long-term value of "good data" but community-level efforts are still sparse, so this Round Table will attempt to come up with strategies for applying Big Data in tribology.

3908877: Lubrication Experts Live Podcast

R. Britton, Lubrication Expert, Rozelle, New South Wales, Australia

Body: Hi! My name is Rafe, and I run a podcast called "Lubrication Experts" on the "Lubrication Explained" YouTube channel. I just became an STLE member and am looking to come to the annual meeting this year. I am planning to use the opportunity to meet up with a number of professionals that I look up to in the field, and record some live interviews for the podcast. I was just going to do the recordings in my hotel room, but would STLE have any interest in making this a live event with an audience? I'd do the recording (~30 minutes) and then we could have a Q&A session after. I'll leave links to both the podcast and YouTube channel below:

Podcast Playlist on YouTube:
https://www.youtube.com/playlist?list=PLu1i0eyydBX0hmPbNwJB621z1wD1r5CVN

YouTube Channel: https://youtube.com/lubricationexplained

Podcast on iTunes: https://podcasts.apple.com/au/podcast/lubrication-experts/id1608527589

Exhibitor Appreciation Hours

Monday and Tuesday, May 22 & 23, 3-4 pm both days

Long Beach Convention Center | Long Beach, California (USA)

Refreshments will be served!

The trade show is a major component of STLE's Annual Meeting. In 2023 STLE is making it even easier for you to fit a visit to the exhibition into your personal itinerary with two hours of dedicated exhibit time—no need to worry about missing a Commercial Marketing Forum presentation, education course or technical session!

Come view the newest products and services from the lubricant industry's leading companies. More than 100 companies from every corner of the industry will be represented and looking to do business with you.

As part of the Exhibitor Appreciation Hour, Evonik Oil Additives USA, Inc. is holding raffles on Monday and Tuesday, May 22 and 23, at 3:30 pm in the exhibit hall. You must be present at **Booth 205** at time of drawing to win. Evonik Oil Additives USA, Inc. is raffling two Yeti soft coolers.

2023 Exhibit Schedule

Monday: Noon–5 pm (Exhibitor Appreciation Hour 3–4 pm)

Tuesday: 9:30 am–Noon & 2–5:30 pm (closed for President's Luncheon - Noon–2 pm. Exhibitor Appreciation Hour 3–4 pm)

Wednesday: 9:30 am–Noon

77th STLE Annual Meeting & Exhibition

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Exhibitors: To reserve a spot at the 2024 STLE exhibition at the Minneapolis Convention Center in Minneapolis, Minn., contact Tracy Nicholas VanEe at (630) 922-3459, ***emeraldcomminc@yahoo.com.***

WEDNESDAY

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STLE's Annual Meeting offers so much programming that keeping track of what's happening when and where can be a challenge. The STLE Mobile App lets you plan your itinerary, schedule appointments and stay on top of fast-breaking meeting updates every minute of the day. Download the mobile app—and don't miss a thing!

In the app, the Annual Meeting (under the Events section) lets you track, schedule and connect with:

- Nearly 500 technical session abstracts—push a button and it's on your itinerary!
- Paper presenters—easily find your favorite authors
- 11 lubrication-specific education courses
- More than 100 exhibitors at the trade show
- Special events and networking opportunities
- Floor plans of the Long Beach Convention Center and exhibition
- Meeting attendees
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- Local dining options
- Meeting updates—stay on top of late-breaking news

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Once in the mobile app, go to Events to find the STLE 2023 Annual Meeting.

For additional questions about the app, please contact Bruce Murgueitio at ***bmurgueitio@stle.org***.

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Overview

Download the STLE Mobile App for the most up-to-date schedule. (pg. 15)

Wednesday, May 24

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Commercial Exhibits and Student Posters
9:30 am – 12:00 pm – **Hall B**

Refreshment Break
10:00 am – 10:30 am – **Hall B**

Education Courses* (8:00 am – 5:00 pm)

- Advanced Lubrication 302: Advanced Lubrication Regimes – **Regency DEFH (Hyatt Hotel)**
- Basic Lubrication 102 – **Regency A (Hyatt Hotel)**
- Metalworking Fluids 250: Understanding and Controlling Metal Removal – **Regency BC (Hyatt Hotel)**

Technical Sessions (8:00 am – 12:00 pm)

- 5A • Lubrication Fundamentals V: Wear and Engines – **101A**
- 5B • Rolling Element Bearings V – **101B**
- 5D • Materials Tribology V – **102B**
- 5E • Tribochemistry II – **102C**
- 5F • Contact Mechanics I – **103A**
- 5G • Tribotesting I – **103B**
- 5H • Commercial Marketing Forum V – **103C**
- 5I • Electric Vehicles V – **104A**
- 5L • Surface Engineering I – **201B**
- 5M • Grease I – **202A**
- 5N • Nanotribology V – **202B**

Lunch (on your own) – 12:00 pm – 1:30 pm

Technical Sessions (1:30 pm – 6:00 pm)

- 6A • Lubrication Fundamentals VI: Innovative Test Methods – **101A**
- 6B • Rolling Element Bearings VI – **101B**
- 6C • Synthetic Lubricants and Hydraulics I – **102A**
- 6D • Materials Tribology VI – **102B**
- 6E • Tribochemistry III – **102C**
- 6F • Contact Mechanics II – **103A**
- 6G • Tribotesting II – **103B**
- 6H • Commercial Marketing Forum VI – **103C**
- 6I • Electric Vehicles VI – **104A**
- 6K • Tribology of Biomaterials I – **201A**
- 6L • Surface Engineering II – **201B**
- 6M • Grease II – **202A**
- 6N • Wear I – **202B**

Refreshment Break
3:00 pm – 3:30 pm – **Foyer**

Exhibition hours

- **Wednesday, May 24** (9:30 am – 12:00 pm)

**Subject to change.*

TIME	SESSION 5A Lubrication Fundamentals V Room 101A	SESSION 5B Rolling Element Bearings V Room 101B
8:00 am – 8:30 am	Lubrication Fundamentals of Threaded Fasteners, B. Bergeron, p. 108	Analyzing the Electrical Transmission Behavior of Rolling Element Bearings, M. Hausmann, p. 109
8:30 am – 9:00 am	Plastic Deformation of a Steel Ball During Impact Loading Against a Lubricated Flat, R. Jones, p. 108	Lubrication Condition Monitoring of Radially Loaded Ball Bearings by Electrical Impedance Method, T. Maruyama, p. 109
9:00 am – 9:30 am	Steel Ball-on-Flat Fretting Test Results Using Grease Lubrication, R. Erck, p. 108	Differences Between the Cathodic and Energetic WEC Fatigue in the View of Bearings in Electric Applications, D. Merk, p. 109
9:30 am –10:00 am	Correlation of Friction and Surface Condition in Rolling-Sliding Contacts with Oil-Impregnated Sinter Materials, N. Sprogies, p. 108	Influence of Electrical Current on Rolling Contact Fatigue, L. Wang, p. 109
10:00 am – 10:30 am	Break	Break
10:30 am – 11:00 am	Detailed Simulating Test Rig Experimental Results for Piston-Ring Lubrication, P. Dellis, p. 108	Detection of Micropitting Evolution Using Acoustic Emission and Electrostatic Sensing Techniques, Z. Tian, p. 109
11:00 am – 11:30 am	Impact of Lubricant Formulation on Aeration Control for Next Generation Passenger Car Motor Oils, L. Crom, p. 108	Damage and Failure in Rolling-Sliding Lubricated Contacts Subjected to Transverse Vibrations, D. Uribe Saenz De Camara, p. 110
11:30 am – 12:00 pm	The Performance of Diesel Engine Oil with an Ashless Antiwear Additive Under Actual Driving Conditions, Y. Shimizu, p. 109	Rolling Element Bearing Defect Detection and Monitoring, J. Yu, p. 110

TIME	SESSION 6A Lubrication Fundamentals VI: Test Methods Room 101A	SESSION 6B Rolling Element Bearings VI Room 101B	SESSION 6C Synthetic Lubricants and Hydraulics I Room 102A
1:30 pm – 2:00 pm	Boundary Lubrication in an Inert Atmosphere – A New Route to Sustainabilit, H. Spikes, p. 123	Numerical Analysis for Tapered Roller Bearing … Roller Profile Based on Running-In Method, R. Cao, p. 126	Liquid Amides – Novel, High Performance Base Oils, C. Ward, p. 127
2:00 pm – 2:30 pm	Differential Topography on the Challenges of Three-Dimensional Characterization of Tribofilms, N. Doerr, p. 124	Efficient Residual Stress Quantification in M50NiL Bearing Steel, D. Isaac, p. 126	Synthetic Esters with The Advent of Electric Vehicles Era: Electric Power Factor & Heat Capacity, Structure-Property-Performance Relationships, H. Kim, p. 127
2:30 pm – 3:00 pm	Achieving Macroscale Superlubricity in Non-Polar Oil by Sacrificial Carbon Nanotube Coating, C. Kumara, p. 124	Prediction of Rotation of a Shrink-Fitted Cup of a Tapered Roller Bearing Under Thermal Loading, V. Pinardon, p. 126	Ionic Lubricant Design Considerations, S. Glavatskih, p. 127
3:00 pm – 3:30 pm	Break	Break	Break
3:30 pm – 4:00 pm	Lubricating Properties of Volatile and Gaseous Fuels, H. Spikes, p. 124	A Generalized Machine Learning Model for Bearing Fault Diagnosis, L. Wang, p. 126	Sustainability – "Energy Savings are Just an Oil Change Away", B. Hess, p. 128
4:00 pm – 4:30 pm	Inevitable Deviations in Surface Profile and System Vibration Determine Tribological Behavior, N. Garbedian, p. 124	Performance Evaluation and Life Estimation of Cryogenic Ball Bearing from Accelerated Life Test Results, Y. Lee, p. 126	Technical and Scientific Perspective from Using Polyglycol on a Composition of Compressor Lubricants, E. Lima, p. 128
4:30 pm – 5:00 pm		Evaluation and Discussion of Tribological Phenomena with the Various Internal Clearance Design, Y. Lee, p. 127	Results of a Novel Bio-Based Oil-Soluble PAG Base Fluid … to Conventional Oil-Soluble PAGs, M. Lutz, p. 128
5:00 pm – 5:30 pm		Diagnosis of Grease Condition Using Dielectric Spectroscopy, S. Iwase, p. 127	Investigation of Varnish Formation & Removal in a High Pressure Piston Pump, S. Kalijaveedu, p. 128
5:30 pm – 6:00 pm		Analytical and Experimental Investigation of Roller Behavior in a Spherical Roller Bearing, A. Shafiee, p. 127	Temperature-Dependent Density and Viscosity Prediction for Hydrocarbons, P. Panwar, p. 128
			Synthetic Lubricants & Hydraulics Meeting (6 :00 pm)

SESSION 5D Materials Tribology V Room 102B	SESSION 5E Tribochemistry II Room 102C	SESSION 5F Contact Mechanics I Room 103A	
Synthesis and Sliding Behavior of Bearing Steel/MAX-Phase Composites, S. Berkebile, p. 110	Atomic-Scale Wear Inside Diamond-Quartz Contacts, J. Bhamra, p. 112	Understanding the Role of Contact Interfaces on Tribo-electrification in Triboelectric Nanogenerators, C. Kumar, p. 114	**8:00 am – 8:30 am**
In-Situ Methods to Study Scuffing Failures of Self-Mated Steels in Real-Time – Part I: Experimental Details, F. Ahmed Koly, p. 110	Analysis of Boundary Lubrication of DLC Using Molecular Dynamics Simulation, H. Washizu, p. 113	A New Approach for Calculating the Contact Heat Transfer Coefficient Based on Real Component Surfaces, P. Wingertszahn, p. 114	**8:30 am – 9:00 am**
In situ Methods to Study Scuffing Failures of Self-Mated Steels in Real-Time – Part II: Initial XRD Analysis, M. Cinta Lorenzo Martin, p. 110	Microscale Tribochemistry of Diamond-Like Carbon Coatings: How the Run-In to Low Friction is Affected by Sliding Distance and Contact Size, B. Borovsky, p. 113	Tribological Issues in the Wheel-rail Interaction: Background and Experiences, A. Mazzu, p. 114	**9:00 am – 9:30 am**
Influence of Dislocation Mobility on the Tribo-Oxidation of Single Crystalline Copper, I. Blatter, p. 112	The Analytical Study of Friction Reduction in Instrumented Single-Cylinder Block, Y. Guan, p. 113	Identification and Analysis of Some New Influencing Parameters on the Surface Damage of Rolling Elements Bearings by a CEL Model, A. Ahyee, p. 114	**9:30 am –10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:30 am**
Study of Cryogenic Friction and Wear Characteristics of Invar 36 Alloy Against Si3N4 Ceramic Balls, B. Wang, p. 112	Tribofilm Formation on Platinum and Pplatinum-Gold Nanocrystalline Alloys, J. Curry, p. 113	Investigating the Contact Area Reduction Over a Nearly Complete Rough Surface Spectrum, R. Jackson, p. 115	**10:30 am – 11:00 am**
Investigate Wear Transition of CoCrMo Alloys After the Heat Treatment, J. Qi, p. 112	Molecular Structure and Environment Dependence of Shear-Driven Chemical Reactions, Y. Li, p. 113	Contact Mechanics of the Patterned Surfaces Generated by Spinodal Decomposition and Amplified Instability, W. Lee, p. 115	**11:00 am – 11:30 am**
Mesoscale Modelling of High Temperature Deformation Mechanisms in Refractory High Entropy Alloys, M. Jones, p. 112	Durability of Materials for Nanoelectromechanical Switches Studied by Scanning Probe Microscopy, C. Qu, p. 114	A Numerical Model for Simulating the Transient Frictional Viscoelastic Sliding Contact, D. Wang, p. 115	**11:30 am – 12:00 pm**

SESSION 6D Materials Tribology VI Room 102B	SESSION 6E Tribochemistry III Room 102C	SESSION 6F Contact Mechanics II Room 103A	
An Investigation into Wear of a Metal-Metal Interface in a Jet Engine, M. Makowiec, p. 130	Encapsulation of Halogen-Free Boron-Based Ionic Liquids within Polymer Microshells, F. Mangolini, p. 131	Macro-Scale Characterization of the Contact Between Ski and Snow, K. Kalliorinne, p. 132	**1:30 pm – 2:00 pm**
Formation of Wear-Protective Tribofilms on Different Steel Surfaces During Lubricated Sliding, A. Khan, p.130	Differences in ZDDP and Ionic Liquid-Based Tribofilms, F. Pape, p. 131	Effects of Mechanical Stimulation on Reconstructed Skin at Different Levels of Maturity, N. Qiao, p. 132	**2:00 pm – 2:30 pm**
Holistic Measurement of the Friction Behavior of Wet Disk Clutches, P. Strobl, p. 130	Mechanochemical Synergy Between Metal Oxide Nanocrystals and Surface-Active Molecules at Lubricated Contacts (Study), P. Nautiyal, p. 131	Impact of Plantar Pressure Variations on the Ski-Snow Contact During the Double Poling Cycle in Cross-Country Skiing, G. Hindér, p. 132	**2:30 pm – 3:00 pm**
Break	**Break**	**Break**	**3:00 pm – 3:30 pm**
Flexible Ultra-Low Friction & Wear Material by Mimicking Articular Cartilage, H. Liu, p. 130	Reactive Molecular Dynamics Simulations of Cyclic Organic Molecules, F. H. Bhuiyan, p. 131	An Application of Hydrodynamic Lubrication Theory to Automotive Windscreen Wipers, B. Graham, p. 132	**3:30 pm – 4:00 pm**
Tribological Performance Evaluation & Enhancement of Bio-Lubricants by using Nano Additives and Ionic Liquids, M. Bhutta, p. 130	Understanding the Effect of Forces on Tribochemical Reaction Rates, W. Tysoe, p. 131	The Effect of Friction Modifier on Piston Rings/Cylinder Liner Friction in Floating Liner Single-Cylinder Engine Tests, A. Alenezi, p. 134	**4:00 pm – 4:30 pm**
Effect of Composition on Friction in Pine Loblloly Biomass Material, M. Cinta p. 130	How are Chemical Reactions Activated in Tribological Interfaces?, S. Kim, p. 132	Relationship Between Hertzian Contact Pressure and Raman Band Shift, K.Delbé, p. 134	**4:30 pm – 5:00 pm**
Materials Tribology Business Meeting	In Situ Observation of the Effect of the Tribofilm Growth on Scuffing in Rolling Sliding Contact, M. Ueda, p. 132	Flows Around a Contacting Asperity Modeled in the Micro and Nanometer Scales, N. Dorcy, p. 134	**5:00 pm – 5:30 pm**
		Contact Mechanics Business Meeting	**5:30 pm – 6:00 pm**

WEDNESDAY >>

TIME	SESSION 5G Tribotesting I Room 103B	SESSION 5H Commercial Marketing Forum V Room 103C	SESSION 5I Electric Vehicles V Room 104A
8:00 am – 8:30 am	Physicochemical and Tribological Comparison of Bio- and Halogen-Based Ionic Liquids, M. H. Rahman, p. 115	ExxonMobil – Empowering the World's Lower Carbon Ambitions Through SpectraSyn™ PAO Basestock Technology in … Lubricant Solutions, L. Bunting, p. 116	Cooling and Lubrication Efforts of Tesla Drive Units and Tesla's Perspective of Future Electric Vehicle Lubricant Development, W. Zhang, p. 118
8:30 am – 9:00 am	Experimental Analysis of Pasting of Brushed DC Motors, R. Dzhafarov, p. 115	ExxonMobil – SpectraSyn™ MaX PAO Technology for Next Generation Electric Vehicle Driveline Fluids, M. Toohey, p. 116	A Study of the Effects of Foam and Antifoam Performance in Electric Vehicle Base Fluids, S. Peerzada, p. 119
9:00 am – 9:30 am	Another Approach to Tribotesting – Enabling AI, D. Drees, p. 115	Advanced Chemical Concepts – The Design and Development of High Performance Metalworking Lubricant and Rust Preventatives, M. Roberts, p. 118	Extrinsic Sustainability Benefits of Esters Suitable for Use in Electric Vehicle Gear and Battery Cooling Systems, B. Warren, p. 119
9:30 am –10:00 am	Measuring Lubricant Viscosity Under Shearing In Situ Using Ultrasound, G. Peretti, p. 116	The Lubrizol Corporation – Innovative Corrosion Inhibitor for Metalworking and Industrial Applications, G. Kirsch, p. 118	Study on the Impact of Dedicated Electric Drive Fluid Properties on Total Efficiency of Drive Unit, P. Cawich, p. 119
10:00 am – 10:30 am	Break	Break	Break
10:30 am – 11:00 am	A Simulated Test Methodology for Screening of Friction, Wear, and Extreme Pressure Properties of Hydraulic Oils, R. Mahapatra, p. 116	Solvay's Solutions for Sustainable Lubricant Additives, J. Mollet, p. 118	Fine Tuning the Structure of Esters to Optimize Their Properties as e-COOLANTS, S. Lucazeau, p. 119
11:00 am – 11:30 am	Measuring the Damping Capacity of Oils, K. Budinski, p. 116	LANXESS Deutschland – A New VOC-Free Temporary Corrosion Inhibitor, Bt Diluted in Water – A Contradiction?, W. Rehbein, p. 118	Shear Stable Ester Thickeners – EVs and Beyond, D. Gillespie, p. 119
11:30 am – 12:00 pm	Effect of Environment on Fuel Lubriity Standards, S. Berkebile, p. 116	Functional Products – Continued Innovation with Novel Tackifiers for Unique Base Stocks, M. Woodfall, p. 118	eTribology – Electrification of and Initial Results from the Mini Traction Machine, P. Lee, p. 119
	SESSION 6G **Tribotesting II** **Room 103B**	**SESSION 6H** **Commercial Marketing Forum VI** **Room 103C**	**SESSION 6I** **Electric Vehicles VI** **Room 104A**
1:30 pm – 2:00 pm	Friction and Lubrication with Dry Powdered Soaps Used in Wire Drawing, M. Schlichting, p. 134	Tannas Noack S2® – Evaporation Loss and Expanded Capabilities – ASTM D5800 and CEC L-040, B. O'Shea, p. 136	The Effect of Esters on the Tribological Performance of Electric Vehicle (EV) Transmission Lubricants, J. Watson, p. 138
2:00 pm – 2:30 pm	Reducing Agglomeration of Gas-Phase Synthesized Graphene in Group IV PAO Base Oil to Enhance Antiwear Performance, G. Krauss, p. 134	Afton Chemical's Key Driver Seminar – Trends and Technological Challenges in Lubricating Greases for Rolling Bearings, F. Berens, p. 136	Shelf-Stable hBN-Based Additive as Sulfur-Free Antiwear and Efficiency Booster for Low Viscosity E-driveline Fluid Applications, P. Moore, p. 138
2:30 pm – 3:00 pm	Image Processing Test Development to Quantify Separation of Gas-Phase Synthesized Graphene from Base Oils & Predict Antiwear Effectiveness, G. Krauss, p. 135		Promising Aspects of Nanolubricants Use for EVs – A Critical Review, W. Ahmed Abdalglil Mustafa, p. 138
3:00 pm – 3:30 pm	Break	Break	Break
3:30 pm – 4:00 pm	Tribological Properties of the Cold Spray Deposited Cermet Coatings, S. Jose, p. 135	BASF Lubricant Solutions for the Future, P. Ma, p. 136	The Effect of Friction Modifiers Under Ultra-Low Viscosity Engine Oils, K. Yamamoto, p. 138
4:00 pm – 4:30 pm	Soot Wear in Heavy-Duty Diesel Engine Oils, T. Kirkby, p. 135	Evonik Corporation: Innovative E-Mobility Solutions from Evonik, A. Rice, p. 136	The Response of Phosphonium Ionic Liquids (ILs) in Lubricating Greases …, E. Conrad, p. 138
4:30 pm – 5:00 pm	Accelerated Endurance Testing of Lubricants Using High-speed KRL Shear, D. Veeregowda, p. 135	Sasol Chemicals – SOFOL® Guerbet Alcohols and Their Derivatives, M. Perkins, p. 136	Additive/Ionic Liquid Concentration on the Electrical & Tribological Properties of an ATF, A. García Tuero, p. 139
5:00 pm – 5:30 pm	Twin Disc Evaluation of Wheel Flange Lubricants and Top of Rail Friction Modifiers, D. Veeregowda, p. 135	Nouryon – Fatty Amine Chemistries and Polymer Technologies for the Lubricant Industry, A. Ortiz, p. 136	… Gear and Bearing Protection with Lower Viscosity Lubricants for Electric Vehicles, H. Tatsumi, p. 139
5:30 pm – 6:00 pm	Tribotesting Business Meeting	Cargill: Dielectric Cooling Fluids & Low Traction Lubricants for Improved EV Performance, S. Davis, p. 136	Combining Durability and Efficiency for Electric Vehicle Transmission Fluids, T. David, p. 139
			Electric Vehicles/Engine & Drivetrain Meeting (6pm)

SESSION 5L
Surface Engineering I

Room 201B

Part-to-Part and Machine-to-Machine Variability in Roughness and Corrosion Properties of Additively Manufactured Stainless Steel, P. Renner, p. 120	8:00 am – 8:30 am
Tribological Behavior of Textured Surfaces Produced by Laser Powder Bed Fusion, T. Martin, p. 120	8:30 am – 9:00 am
Development and Performance Evaluation of Novel Surface Polishing Technique for Additively Manufactured Components, K. Uday Venkat Kiran, p. 120	9:00 am – 9:30 am
Friction and Deformation of Additively Manufactured Micro/Nano-Hierarchical Structures with Different Structural Stiffness, M. Afshar Mohajer, p. 120	9:30 am –10:00 am
Break	10:00 am – 10:30 am
A Comparative Analysis in Tribo-Mechanical Behavior of Cold Rolled and Additively Manufactured Nickel Titanium Alloy, H. Choi, p. 120	10:30 am – 11:00 am
Additively Manufactured Inconel 625 Subjected to Shot Peening and Laser Peening Processes … A. Beheshti, p. 120	11:00 am – 11:30 am
Exploring the Wear Resistance of Additively Manufactured Al Parts for Future Lunar Exploration via Custom Developed Testing Strategies, P. Das, p. 121	11:30 am – 12:00 pm

SESSION 6K
Tribology of Biomaterials I

Room 201A

The Role of Gradient Layer on Depth-Dependent Adhesion in Hydrogel Using AFM Nano-indentation, M. Hasan, p. 139	1:30 pm – 2:00 pm
Dynamic Viscoelasticity Measurement of Hydrated Polymer Brush Film in Narrowing Shear Gap, F. Lin, p. 139	2:00 pm – 2:30 pm
Relationship Between Friction Coefficient and Permeability of Physically and Chemically Crosslinked Hydrogels, N. Chowdhury, p. 139	2:30 pm – 3:00 pm
Break	3:00 pm – 3:30 pm
Sliding Friction Through Dislocation Glide in Shape Complementary Soft Interfaces, J. Kaur, p. 140	3:30 pm – 4:00 pm
Study of Biological Interfaces – From Cartilages to Personal Care Products, K. Pondicherry, p. 140	4:00 pm – 4:30 pm
… Solvent-Cast 3D-Printed Peptide-Polymer Scaffolds for Osteochondral Tissue Regeneration, S. Lazarte, p. 140	4:30 pm – 5:00 pm
In Situ Measurements of Syringe-Stoppers Contact Interfaces in Deep Cold Storage …, A. DeLong, p. 140	5:00 pm – 5:30 pm
Biotribology Business Meeting	5:30 pm – 6:00 pm

SESSION 6L
Surface Engineering II

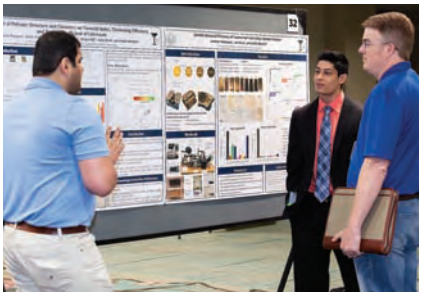
Room 201B

Tribological and Tribo-Corrosion Mechanisms of Al7075-T6 alloy by Ultrasonic Nanocrystal Surface Modification, A. Amanov, p. 140	1:30 pm – 2:00 pm
A Multiscale Modeling System for Surface Texturing a Radial Pump Plunger to Improve Tribological Performance, H. Soewardiman, p. 141	2:00 pm – 2:30 pm
Interaction Between Lubricants and Surface Texture Under EHL Conditions, M. Syafiq Abd Aziz, p. 141	2:30 pm – 3:00 pm
Break	3:00 pm – 3:30 pm
… Properties of Frictional Hysteresis Loops in Metallic Contacts by Surface Engineering, M. Jonkeren, p. 141	3:30 pm – 4:00 pm
… Polymer Brushes and Laser Surface Texturing to Achieve Durable Superlubricity, S. Vladescu, p. 141	4:00 pm – 4:30 pm
Increasing Tire Tread Ice Traction by Superhydrophobic Laser Texture, M. Wangenheim, p. 141	4:30 pm – 5:00 pm
Surface Engineering Business Meeting	5:00 pm – 5:30 pm

WEDNESDAY >>

TIME	SESSION 5M Grease I Room 202A	SESSION 5N Nanotribology V Room 202B
8:00 am – 8:30 am		Understanding the Corrosion and Wear at Nanoscale Interface Using Machine Learning Technique, R. Zhang, p. 122
8:30 am – 9:00 am	Role of the Grease Components on the Overall Frictional Response of a Greased Contact Subjected to Low-Sliding Velocity Conditions, F. Massi, p. 121	Frictional Behavior of Surfaces Textured with Various Core-Shell Nanostructures, C. Phelan, p. 122
9:00 am – 9:30 am	Unraveling the Role of Particle-Particle Contacts on Microscopic, Rheological and Tribological Characteristics of Nanoenhanced Greases, J. Uhryn, p. 121	Effect of Oxidation of Metal Surface on Additive Adsorption and Friction Property, L. Sun, p. 122
9:30 am –10:00 am		Molecular Friction Models for Molecular Adsorbates, W. Tysoe, p. 123
10:00 am – 10:30 am	Break	Break
10:30 am – 11:00 am	The Matrix Revisited: Exploration of Additive Choice with Different Thickener Types, J. Kaperick, p. 121	Tribological Behavior of Graphene Quantum Dots as Novel Additives for Green Lubrication, I. Nadeem, p. 123
11:00 am – 11:30 am	Ionic Materials in Greases: Influence on Lubrication and Electric Conductivity, S. Glavatskih, p. 122	Probing the Mechanical Properties of Soot to Understand the Tribology of Contaminated Diesel Engine Oils, A. Al Sheikh Omar, p. 123
11:30 am – 12:00 pm	OBCaS Grease Green One and Customized One, G. Notheaux, p. 122	Failure Mechanisms of Two Nano Adhesives Based on MWCNTs and SiC Nanoparticles, J. Bijwe, p. 123
	SESSION 6M **Grease II** **Room 202A**	**SESSION 6N** **Wear I** **Room 202B**
1:30 pm – 2:00 pm	Shear Properties of Various Greases in Micrometer-Order Gap, H. Chun, p. 142	Adjusting for Running-In: Extension of the Archard Wear Equation, M. Varenberg, p. 142
2:00 pm – 2:30 pm	Impact of Thermo-Mechanical Aging of Grease During Churning on Grease Properties and Life, S. Chatra K R, p. 142	An Advanced Numerical Model for Wear, J. Choudhry, p. 142
2:30 pm – 3:00 pm	Effects of Shear Aging on Oil-Separation Properties of Lubricating Greases, F. Hogenberk, p. 142	Wear Behavior of Metallic Part Repaired by an Additive Manufacturing Process, T. Zurcher, p. 142
3:00 pm – 3:30 pm	Break	Break
3:30 pm – 4:00 pm	Bevel Gear Grease – A Sustainability Case Study, J. Leckner, p. 142	Tribology Analysis of Additive Manufactured, Nickel-Based Super Alloys, K. Shirvani, p. 142
4:00 pm – 4:30 pm	Benchtop Tribological Characterization of Electric Motor Greases for Hybrid Bearings, A. Kumar, p. 142	Effects of Temperature and Lubricant on Reciprocating Sliding Wear Behavior of HNBR/FKM, Z. Qiao, p. 142
4:30 pm – 5:00 pm	Grease Business Meeting	Computational Modelling of the Antiwear Effect of Zinc Dialkyldithiophosphate Tribofilms in Mixed Mode Lubricated Contact, R. Anderluh, p. 142
5:00 pm – 5:30 pm		Wear Business Meeting

Support Young Tribologists and see the Latest Industry Research at #STLE2023



More than 40 student and early career posters will be on display **Monday through Wednesday, May 22-24** in **Hall B** during the STLE Annual Meeting. Students and early career professionals from around the world will be participating and showcasing the latest industry research. Attendees will be able to review tomorrow's ideas and talent in the field of tribology. Posters will be judged by a conference committee, and cash stipends will be given out to the best posters. Winners will be recognized during the President's Luncheon on Tuesday, May 23.

Session 5A | 101A

Lubrication Fundamentals V: Wear and Engines

Session Chair: Xin He, Solvay, Levittown, PA

Session Vice Chair: Nicole Doerr, AC2T research GmbH, Wiener Neustadt, Austria

8:00 am – 8:30 am

3805121: Lubrication Fundamentals of Threaded Fasteners

Bryan Bergeron, Mark Guenther, A.W. Chesterton, Groveland, MA

Properly designed and applied anti-seize to threaded assemblies is critical to support global industrial demands in various markets and applications. Yet most lubrication engineers focus and have expertise on formulated oil and grease. This comprehensive session will provide a broad overview of anti-seize and bolting systems. It will include risks and failure modes, chemical compositional considerations, frictional coefficient and nut factor, lubrication, and tensioning procedures. Recognition of some OEM and end-user specifications and concerns associated with the formulation are indicated. There will be emphasis on particle size, compatibility, and temperature limits of typical ingredients. Test methodology by use of a Skidmore-Wilhelm apparatus is introduced. Impact of scatter on tension is shown through various calculations.

8:30 am – 9:00 am

3833745: Plastic Deformation of a Steel Ball During Impact Loading Against a Lubricated Flat

Roland Jones, Hugh Spikes, Amir Kadiric, Imperial College London, London, United Kingdom

When a ball impacts a flat covered with a thin lubricant film, a pocket of high-pressure oil is entrapped between them. This phenomenon has been investigated in the past to study lubricants at very high pressures. In contrast, this paper studies the potential for such impact to cause plastic deformation of the ball which has practical implications in machine elements such as rolling bearings. The study uses a custom-made ball impact rig with high-speed duo-chromatic interferometry to observe the transient film thickness and pressure distributions during impact. It is found that for certain conditions, and in particular certain lubricant viscosities, the hard steel ball suffers unexpected plastic deformation at loads which would be within its elastic limit if dry contact is considered. Results are discussed in terms of the ability of the lubricant to concentrate the impact pressure over an area smaller than the equivalent dry contact.

9:00 am – 9:30 am

3812529: Steel Ball-on-Flat Fretting Test Results Using Grease Lubrication

Robert Erck, Nicholaos Demas, Aaron Greco, Argonne National Laboratory, Lemont, IL

Fretting wear experiments were conducted using a ball on flat geometry. Results are reported for type 52100 steel balls sliding against steel flats using commercial greases. Flat and ball volume losses were measured using white-light interferometry. Stroke lengths were typically 150 micrometers, although 90 micrometers to 540 micrometer strokes were used. Tests were nominally performed at 52 N at a frequency of 150 Hz. Oxidation was observed in dry sliding conditions. For some samples, at small stroke lengths pitting occurred in the occluded area, absent for longer strokes.

9:30 am – 10:00 am

3811763: Correlation of Friction and Surface Condition in Rolling-Sliding Contacts with Oil-Impregnated Sinter Materials

Nicolai Sprogies, Thomas Lohner, Karsten Stahl, Technical University of Munich, Garching, Bavaria, Germany

Whereas self-lubricating journal bearings having oil impregnated are state of the art, the lubrication method has been poorly investigated for rolling-sliding contacts in gears. In this study, self-lubrication via oil impregnation of sinter metals is investigated for gear applications. Therefore, the tribosystem of a gear contact is transferred to a rolling-sliding model contact. The friction and temperature behavior of various material-surface-pairings are analyzed by a twin-disk tribometer. High-resolution 3D topographical measurements during tests are used to record the surface alteration. The experimental results show the functionality of self-lubricating rolling-sliding contacts under high load and sliding. The friction is drastically reduced, and the lifetime strongly increased compared to dry rolling-sliding contacts. The surface analyses emphasize a significant influence of the surface condition and of the surface porosity on the self-lubricating tribosystem.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3801630: Detailed Simulating Test Rig Experimental Results for Piston-Ring Lubrication

Polychronis Dellis, ASPETE, Athens, Attiki, Greece

Experimental data and analysis is given regarding cavitation in oils evident in LIF, pressure and capacitance measurements. Parametric study for minimum oil film thickness through the stroke and LIF for point measurements were the basic tools. A pressure sensor provided data that were combined with imaging via a modified liner and high-speed camera. Power losses were derived from friction measurements. These modifications and new additions were imposed prior to engine testing in two different set-ups. Different forms of cavitation were identified, and their shape and size are dictated from operating conditions and lubricant properties. The formulation affects cavitation behavior. Further engine studies were conducted after its initial identification, to get a clearer picture of the different stages. Signals are analyzed for the experimental set-ups and interpreted according to the lubricants' properties. Results are presented in combination to cavitation initiation, size, and number.

11:00 am – 11:30 am

3830729: Impact of Lubricant Formulation on Aeration Control for Next Generation Passenger Car Motor Oils

Lori Crom, Matthias Eggenstein, Robert Mainwaring, Carl Stow, Neil Elsby, Shell, London, United Kingdom; Mark Jackson, Matt Irving, Infineum, Abingdon, United Kingdom

Oil aeration is worrisome because it can inhibit lubrication in critical contacts, compromise the actuation of hardware components, reduce heat transfer, and accelerate oil oxidation. The amount of air in an oil represents the balance of entrainment and release. Air entrainment is not desirable and is affected by several factors such as high engine speed, reduced oil volume, and low oil viscosity. Release is desirable and is affected by several factors such as low oil viscosity, high temperature, and effective antifoam. Some of these sensitivities conflict, making strong performance with low viscosity oils challenging. We will discuss operational and formulation factors that impact low viscosity oil aeration. The impact of relevant formulation changes and scrutinizing bench methods to pre-screen oils for engine testing will be shared. Results enabled development of a next generation passenger car engine oil, with long oil drain interval and full compatibility with hybrid application.

11:30 am – 12:00 pm

3812176: The Performance of Diesel Engine Oil with an Ashless Antiwear Additive Under Actual Driving Conditions

Yasunori Shimizu, Moritsugu Kasai, Idemitsu Kosan Co., Ltd., Chiba, Japan

In order to comply with emission standards for vehicles, after-treatment devices such as oxidation catalysts and DPF are installed. It has, however, been reported that metals (ash) in engine oil clog the filter and deteriorate the DPF performance. From this background, low ash engine oils have been studied. While ZDDP has been historically used as an anti-wear additive in engine oil, zinc also accumulates in the DPF as ash. From this point of view, the authors have developed a diesel engine oil containing an ashless anti-wear additive instead of ZDDP. After confirming its valve train wear protection in engine bench tests, the authors widely conducted field tests using the developed engine oil and it was confirmed that the oil showed good oil properties during the tests.

Session 5B | 101B

Rolling Element Bearings V

Session Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

Session Vice Chair: Kushagra Singh, Purdue University, West Lafayette, IN

8:00 am – 8:30 am

3807966: Analyzing the Electrical Transmission Behavior of Rolling Element Bearings

Maximilian Hausmann, Philipp Liehr, Eckhard Kirchner, Technical University of Darmstadt, Darmstadt, Germany

In order to meet requirements for the digitalization of mechanical engineering, current research shows a trend towards the sensory use of electrical properties of machine elements. Especially, the electrical capacitance of rolling element bearings can be used to derive its operating condition. In order to acquire sensor data in-situ in a rotating mechanical system, the sensor signal must be transmitted to an evaluation unit outside of the system. The transmission via the existing mechanical structure offers a potential solution. Using frequency response analysis, the electrical transfer function of radial rolling element bearings is analyzed in different working points and lubrication conditions for the first time. The effects of speed, axial and radial load, lubricant temperature as well as the type of lubricant, in this case grease, oil and graphite, are analyzed. With this, significant influencing variables on the electrical signal transmission behavior can be derived and described.

8:30 am – 9:00 am

3808347: Lubrication Condition Monitoring of Radially Loaded Ball Bearings by Electrical Impedance Method

Taisuke Maruyama, Shunsuke Iwase, Masayuki Maeda, NSK Ltd., Fujisawa, Kanagawa, Japan; Ken Nakano, Yokohama National University, Yokohama, Kanagawa, Japan

In the previous study, the electrical impedance method has been developed, which measures the thickness and breakdown ratio of oil films simultaneously by applying an alternating voltage to the contact area. However, this method can only monitor lubrication conditions in ball bearings under axial load, which means that all contact areas are uniform. In this study, the electrical method has been improved so that it is also applicable to radially loaded ball bearings.

9:00 am – 9:30 am

3812184: Differences Between the Cathodic and Energetic WEC Fatigue in the View of Bearings in Electric Applications

Daniel Merk, Jörg Franke, Jörg Loos, Schaeffler Technologies, Schweinfurt, Bavaria, Germany

Beside the Hertzian contact stresses, so-called additional loads, like electrical currents, can act on rolling element bearings. If these additional loads exceed a critical limit, they potentially lead to premature bearing failures, provoked by White Etching Cracks (WECs). The influence of the "lubricant chemistry", or the lubricants, in general, is therefore strongly depending on the type of additional load. In specific cases, this lubricant influence can vary from "minor" to "dominant". The same fact is valid for the influence of the electrical polarity or the degree of mixed friction. The presentation describes the cathodic and energetic WEC and why the influences are strongly depending on the specific operating conditions.

9:30 am – 10:00 am

3808483: Influence of Electrical Current on Rolling Contact Fatigue

Ling Wang, nCATS, Southampton, United Kingdom

The life of rolling element bearings (REBs) under electrification especially in machinery that are subject to high voltages, has shown to be significantly reduced. With rapid growth of electric vehicles (EVs), responding to the global target of zero carbon emissions, the concerns on REB life in EVs is also increasing. To understand the influence of electrification on rolling contact fatigue (RCF), experiments have been conducted on a TE74 twin-roller machine for oil-lubricated rolling contact under a range of conditions while a DC voltage is applied. The test results show that the electric current has induced micro-pitting wear on the roller surface. Electrical charging-discharging events across the oil-lubricating film have been observed and a correlation between the magnitude of discharge current and the average area of micro-pitting is seen. The results also show that the average size of micro-pitting is influenced by the level of discharge current at the roller contact interface.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3812896: Detection of Micropitting Evolution Using Acoustic Emission and Electrostatic Sensing Techniques

Zaihao Tian, Shuncai Wang, Robert Wood, University of Southampton, Southampton, United Kingdom; Daniel Merk, Schaeffler Technologies, Schweinfurt, Bavaria, Germany

Rolling bearings perform under most operating conditions without any problems, but there are certain conditions where micropitting appears. Considerable work has been conducted on investigating drivers of micropitting based on post-test inspections. However, due to its fast process, micropitting evolution has been poorly captured by online sensing. This work aims to achieve detection of micropitting evolution using acoustic emission (AE) and electrostatic (ES) sensing techniques. A twin-disc tribometer was used to perform rolling contact fatigue tests. Latest results showed how micropits were produced and various wear patterns were identified. Sensor data indicated the AE sensing was sensitive to asperity contact conditions and micropitting propagation, and the ES sensing was capable of detecting tribofilms and micropits. The combination of both measurement techniques allows a general understanding about the root cause, as well as the propagation phase of micropits.

5B

11:00 am – 11:30 am

3834175: Damage and Failure in Rolling-Sliding Lubricated Contacts Subjected to Transverse Vibrations

David Uribe Saenz De Camara, Amir Kadiric, Imperial College London, London, United Kingdom; Armando Felix-Quiñonez, SKF Research & Technology Development, Houten, Netherlands

In a number of practical bearing applications, the rolling-sliding contacts between rolling elements and raceways are subjected to transverse vibrations. We have previously shown that such vibrations can increase the likelihood and the extent of surface damage, particularly micropitting. This talk attempts to provide further insight into the mechanisms behind the observed damage by studying the effect of transverse vibrations on lubrication conditions as well as their impact on the rate of accumulation of asperity stress cycles. The study employs a triple-disc contact fatigue rig which has been modified to incorporate an electrodynamic modal shaker to impose transverse vibrations over a wide range of strokes and frequencies. The lubrication conditions are monitored in parallel to damage development using an electrical capacitance method. The results are presented to illustrate the effect of transverse stroke length, frequency and sliding speed on contact damage and oil film thickness.

11:30 am – 12:00 pm

3812130: Rolling Element Bearing Defect Detection and Monitoring

John Yu, Baker Hughes, Marietta, GA

Vibration was measured with several accelerometers on the input shaft of an extruder using an on-line remote monitoring system. Though the vibration amplitudes were below the acceptable limit for over a year period, damages on two rolling element bearings were believed to have occurred based on observed vibration signatures. Vibration frequencies and amplitudes were monitored via both normal and demodulated spectra. One damage appeared to be on the inner race of a bearing, and the other on the outer race of a second bearing. An outage was well scheduled based on vibration signatures and readings from both normal and demodulated spectra, along with plant operational needs. Inspection results matches diagnosed inner and outer race damages and extent. Lessons are learned on how vibrations from normal and demodulated spectra should be looked upon to make a correct decision of timing of bearing replacement. Vibration signatures versus damage severity are also discussed.

Session 5D | 102B

Materials Tribology V

Session Chair: Kylie Van Meter, Florida State University, Tallahassee, FL

Session Vice Chair: Nikhil Murthy, US Army Research Laboratory, Aberdeen Proving Ground, MD

8:00 am – 8:30 am

3813123: Synthesis and Sliding Behavior of Bearing Steel/MAX-Phase Composites

Stephen Berkebile, Nikhil Murthy, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Caleb Matzke, Shawn Ruggiero, Emily Dahlke, Abdulrahman Aldossary, Surojit Gupta, University of North Dakota, Grand Forks, ND

Mechanical interfaces lubricated with low viscosity fuels require materials that can resist damage with little aid from a lubricating fluid film. We hypothesize that MAX phases (layered, hexagonal carbides) incorporated into steel reduce wear of the steel by increasing hardness. Powder metallurgy $100Cr_6$ steel and composite ($100Cr_6$ steel – 5 vol% Cr_2AlC) samples were densified in an unpressurized furnace using argon atmosphere at 1400˚C for 30 minutes, then heat treated at 840˚C for 23 minutes in air with water quench. We determined the microstructure of steel/MAX-phase composites and effects on wear and coefficient of friction when lubricated by fuels of varying chemistries (ethanol, jet fuel) compared to dry sliding. The addition of Cr_2AlC was observed to increase the hardness of the steel through unique structural formations during heat treating that originated from the Cr_2AlC particles. We will discuss the tribological effects of this transformation in the various fuels.

8:30 am – 9:00 am

3831212: In-Situ Methods to Study Scuffing Failures of Self-Mated Steels in Real-Time – Part I: Experimental Details

Farida Ahmed Koly, Arnab Bhattacharjee, David Burris, University of Delaware, Newark, DE; Nikhil Murthy, Stephen Berkebile, U.S. DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Ben Gould, Oyelayo Ajayi, Maria Cinta Lorenzo Martin, Argonne National Laboratory, Lemont, IL

Scuffing, a type of wear found in highly stressed or poorly lubricated contacts, is characterized by severe plastic deformation of the near surface material. As with other tribological phenomena, scuffing has proven difficult to study directly due to a lack of access to the contact interface. We developed a novel instrument to study scuffing failures within lubricated, self-mated steel contacts in-situ using X-rays in transmission. We discuss the instrument design approach and preliminary scuffing experiments to demonstrate reliable achievement of scuffing. These experiments used fuel-lubricated 52100 and 1045 steels at moderate (cm/s) sliding speeds in reciprocating contacts. Our preliminary synchrotron experiments focused X-rays within the contact area (to a depth of ~ 20 m) and collected full powder diffraction rings throughout each test. We will review these experiments briefly here, but detailed analysis of these diffraction data will be reserved for Part II of this talk.

9:00 am – 9:30 am

3818526: In situ Methods to Study Scuffing Failures of Self-Mated Steels in Real-Time – Part II: Initial XRD Analysis

Maria Cinta Lorenzo Martin, Dawid Bachnacki, Trenton Culverhouse, Zachary Jernigan, Jun-Sang Park, Oyelayo Ajayi, Benjamin Gould, Argonne National Laboratory, Lemont, IL; Farida Koly, Arnab Bhattacharjee, David Burris, University of Delaware, Newark, DE; Nikhil Murthy, Scott Walck, Stephen Berkebile, U.S. DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Scuffing, a type of wear found in highly stressed or poorly lubricated contacts, is characterized by severe plastic deformation of the near surface material. As with other tribological phenomena, scuffing has proven difficult to study directly due to a lack of access to the contact interface. This Part II talk presents initial analysis of real-time characterization of scuffing failure of lubricated steel in a reciprocating contact using high-energy high-speed synchrotron X-ray diffractometry. We conducted in-situ experiments, where XRD from the contact interface was continuously acquired during scuffing tests, and ex-situ experiments, consisting of 1-micron step XRD depth profile taken before and after scuffing tests to evaluate structural changes up to 150 microns depth from the contact. Initial results showed changes in the lattice parameter, peak intensity and peak width of existing crystallographic planes rather than the emergence of any new crystal phases or transformations.

The transportation industry and its fluids are evolving, and Savant Labs are at the forefront of electric vehicle drivetrain fluids testing. Developing and testing fluids engineered to meet the specific requirements for electric vehicles is critical to providing protection and assurance. The lubrication and cooling demands of electrical systems present new challenges to fluid formulations, primarily copper corrosion and potential for conductive deposit formation in EV powertrains. Savant Labs run a full slate of fluid property testing and can perform two crucial tests that have been uniquely developed to address these emerging concerns:

Conductive Deposit Test (CDT): Reveals destructive conductive deposits forming from the chemical reaction of the lubricating fluid and copper at elevated temperatures under low voltage, electrified conditions, both in the fluid and vapor state.

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WCT: Savant Labs, in partnership with Lubrizol, is exclusive test provider in North America ■ CDT: Equipment developed and patented by Tannas

A WORLD OF LUBRICATION UNDERSTANDING

5D

9:30 am – 10:00 am

3812298: Influence of Dislocation Mobility on the Tribo-Oxidation of Single Crystalline Copper

Ines Blatter, Julia Rau, Christian Greiner, Karlsruhe Institute of Technology, Karlsruhe, Baden-Württemberg, Germany; Baptiste Gault, Max Planck Institute for Iron Research, Düsseldorf, Germany; Lisa Belkacemi, Leibniz-Institute for Materials Oriented Technologies (IWT), Bremen, Germany

Metallic surfaces subjected to tribological loading often suffer from accelerated oxidation, which can significantly influence the resulting friction and wear behavior. Therefore, it is important to better understand the underlying mechanisms to engineer materials with better friction and wear properties. By running experiments with varying cycle numbers on a copper-sapphire model system, we were able to monitor the sequence of stages in the microstructural evolution and oxide formation. As previous research suggested that dislocations act as high-diffusivity pathways, two experimental setups were chosen that allowed for either high or low dislocation mobility. It was shown that this strongly influences the oxidation behavior. Atom probe tomography (APT) was performed to identify possible diffusion pathways. In the long term, understanding the underlying and fundamental mechanisms of tribooxidation will enable the targeted development of friction – and wear-optimized surfaces.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3801462: Study of Cryogenic Friction and Wear Characteristics of Invar 36 Alloy Against Si3N4 Ceramic Balls

Bin Wang, Yanbao Guo, Zheng Zhang, Deguo Wang, China University of Petroleum, Beijing, China

A pin-on-disk cryogenic tribotester was designed and constructed for studying cryogenic tribological behavior of Si_3N_4 ceramic balls against Invar 36 alloy under dry condition, and the test temperature ranges from 293 K to 77 K. The sliding friction and wear experiments under four different loads and temperatures were carried out on the tribotester. The results indicated that the Invar 36 alloy showed better tribological characteristics at all test parameters compared with G95cr18 alloy. Both friction coefficient and wear rate dropped with the decreasing temperature. From 293 K to 195 K, the wear mechanism of Invar 36 alloy material is mainly abrasive wear. However, lower contact stress and surface temperature rise at 77 K, and approximately weakened the abrasive wear, showing an extremely low wear rate. The aforementioned is significant for improving the study of tribological characteristics of materials under cryogenic condition.

11:00 am – 11:30 am

3812729: Investigate Wear Transition of CoCrMo Alloys After the Heat Treatment

Jiahui Qi, The University of Sheffield, Sheffield, United Kingdom

This study reports that the wear rate of the heat-treated CoCrMo alloy shows a sudden transition of more than 5-fold when the load/contact pressure increases from 45N (3.6GPa) to 50N (3.7GPa). Heat treatment was used to change the structure of the commercially available CoCrMo from the initial face-centred cubic (γ-fcc) with a small amount of hexagonal close-packed (ε-hcp) to predominantly hcp ε-phase with dispersed nanoscale precipitates of σ-phase. PeakForce QNM was used to quantitatively map the local mechanical properties of the surface at the nanoscale. High-resolution transmission electron microscopy (HRTEM), scanning transmission electron microscope (STEM), energy-dispersive X-ray spectroscopy (EDX), and precession electron diffraction (PED) integrated with the TEM is used to characterize the structure and chemical composition of the worn surface and tribofilm. The possible reason for the wear transition was discussed.

11:30 am – 12:00 pm

3843109: Mesoscale Modelling of High Temperature Deformation Mechanisms in Refractory High Entropy Alloys

Morgan Jones, Irene Beyerlein, University of California, Santa Barbara, Santa Barbara, CA; Nicolas Argibay, DOE Ames Laboratory, Ames, IA

In sectors such as aerospace, automotive, and power generation, a great deal of effort is dedicated to developing high-performance alloys that can withstand increasingly harsh operating conditions. Refractory high entropy alloys (RHEAs) are, in general, noted for their superior mechanical properties. Their remarkable phase stability, insensitivity to thermal history, and solution strengthening mechanisms makes them an ideal candidate to replace components made from traditional Ni-based superalloys. Unfortunately, the deformation mechanisms of RHEAs at high temperatures are not well understood, and the possible compositional combinations of new RHEAs are nearly limitless. Computational techniques can be employed to inform the design of next-generation superalloys. We present results of dislocation dynamical processes in RHEAs over a range of high temperature conditions using a mesoscale, energy-based model. Cross-slip, energetic landscape, and edge versus screw mobility are discussed.

Session 5E | 102C

Tribochemistry II

Session Chair: Behnoosh Baboukani, University of California, Berkeley, Berkeley, CA

Session Vice Chair: TBD

8:00 am – 8:30 am

3832309: Atomic-Scale Wear Inside Diamond-Quartz Contacts

Jagjeevan Bhamra, James Ewen, Carlos Latorre, Daniele Dini, Imperial College London, London, United Kingdom; John Bomidi, Marc Bird, Baker Hughes, The Woodlands, TX

Diamond surfaces wear when sliding against silicon oxides, despite them being much softer materials. Here, we use nonequilibrium molecular dynamics (NEMD) simulations with a reactive force field for studying the wear of hemispherical single-crystal diamond tips sliding on -quartz surfaces under a wide range of temperatures and loads. Diamond wear on -quartz is initiated by the formation of C-O interfacial bonds, which is followed by C-C cleavage, and ultimately CO_2 formation. At low loads, the wear rate of the diamond tip increases exponentially with both temperature and normal stress, consistent with stress-augmented thermally activated (SATA) wear models. At high loads, the NEMD simulation data deviate from the SATA model and the wear rate becomes less sensitive to the normal stress. The wear rate data over the entireload range can be accurately described using the single-asperity multibond wear model depicting the process of wear as interfacial bond formation and breaking.

8:30 am – 9:00 am

3833419: Analysis of Boundary Lubrication of DLC Using Molecular Dynamics Simulation

Hitoshi Washizu, HIrotoshi Akiyama, Rio Nakae, Yosuke Hamano, Koshiro Torimoto, Yudai Tanaka, Ryuichi Okamoto, University of Hyogo, Kobe, Japan

Improving lubrication using DLC coating is still in progress. If tribo-catalytic materials such as zirconia as the counter body of the friction, ultra-low friction such as Friction Fade Out (FFO) phenomena is observed in hydrogen with alcohol gas environment. Recently, specific adsorption of additives in oil to the DLC is reported. Our approach is to use molecular dynamics (MD) simulation with reactive force field to understand these phenomena. Since the experimental phenomena contain complex and sequential chemical reaction part, we use MD in some phenomena divided from the whole sequence. For example, adsorption and reaction of alcohol molecules on zirconia is analyzed by MD. Then polymerization of the molecules is discussed using radical organic species. In each step, we found important aspect of each chemical reaction step. The importance of zirconia is found replacing DLC substrate by Ni metal. The specific adsorption of additives to the DLC surface is also discussed.

9:00 am – 9:30 am

3812901: Microscale Tribochemistry of Diamond-Like Carbon Coatings: How the Run-In to Low Friction is Affected by Sliding Distance and Contact Size

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

We use an indenter probe to press a microscopic stainless-steel sphere onto a hydrogenated diamond-like carbon (H-DLC) coating that forms the surface of a quartz crystal microbalance (QCM). By resonating the QCM in its fundamental shear mode, we induce sliding friction at the interface, with track lengths in the nanometer range and frequencies near 5 MHz. The QCM performs friction measurements while the normal load is fixed at values between 5 μN and 1 mN. We demonstrate that 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 causes a substantial reduction in friction detected by the QCM. We associate this reduction with the "running-in" behavior of H-DLC and its shear plane chemistry. We explore relationships between the sliding distance, contact size, and the tribochemistry of the transition to low friction sliding.

9:30 am – 10:00 am

3805937: The Analytical Study of Friction Reduction in Instrumented Single-Cylinder Block

Yue Guan, Jules Galipaud, Frédéric Dubreuil, Maria-Isabel De Barros Bouchet, Ecole Centrale de Lyon, Écully, France; Johnny Dufils, Etienne Macron, IREIS/HEF GOURPE, Andrézieux-Bouthéon, France; Fabrice Dassenoy, LTDS/ECL, Ecully, France

Diamond-carbon like (DLC) coating has been widely used for improving friction reduction in engines. However, the interactions between DLC and commercially available fully formulated engine oils are still unclear. Here, a commercially available 5W30 lubricant was employed for ring-on-disk sliding tests in DLC self-mated and DLC/steel mixed configuration. Different parameters as sliding velocity and contact pressure were tuned to investigate their impact on the tribological behavior. Post-tests, the wear track was fully characterized by SEM/EDS, AFM, XPS and FIB-TEM/EDS to interpret the relation between tribological performances and tribofilm's chemical nature and structure. The results show a decrease of CoF as the contact pressure increased in mixed/boundary lubrication regime for steel/DLC pair. This behavior could be related to the increase in calcium carbonate amount in tribofilm as the function of contact pressure, at the expense of iron oxide.

10:00 am – 10:30 am – Break

10:30 am- 11:00 am

3910297: Tribofilm Formation on Platinum and Platinum-Gold Nanocrystalline Alloys

John Curry, Tomas Babuska, David Adams, Michael Dugger, Frank DelRio, Sandia National Laboratories, Albuquerque, NM; Camille Edwards, Filippo Mangolini, The University of Texas at Austin, Austin, TX

This work presents new analysis detailing the film composition and chemical bonding of tribofilms formed under shear on Pt, Pt0.99Au0.01, Pt0.97Au0.03, Pt0.90Au0.10 thin films. Near Edge X-ray Absorption Fine Structures (NEXAFS) spectroscopy, X-ray photoelectron spectroscopy (XPS) and reflection electron energy loss spectroscopy (REELS) was performed on tribofilms formed on all four compositions across six different contact pressures. Nearly all films tested, including pure Pt were able to produce low friction tribofilms, yet Pt0.90Au0.10 films were the only to consistently form these tribofilms across multiple contact pressures and in a manner where the catalytic yield (assessed via XPS) exhibited an exponential behavior with contact pressure. Hydrogen content and band gap (assessed via REELS) also increased with contact pressure for Pt0.90Au0.10 films suggesting a more polymer-like tribofilm at higher loads. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

11:00 am – 11:30 am

3811899: 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

Tribochemistry deals with dynamic interfacial processes that lead to formation of beneficial tribofilms. For a better mechanistic understanding, we studied the tribopolymerization of C6 molecules with different internal ring strain energy on stainless steel in N_2, O_2, and H_2. In N_2 and H_2, strain-free cyclohexane showed the lowest reactivity among the three tested. A similar trend in the reaction yield of three precursors was found in reactive molecular dynamics simulations. Reaction yield produced in H_2 was lower than in N_2. When tribofilms were analyzed with Raman, spectral features of diamond-like carbon (DLC) were observed. However, these features originated not from the tribofilm formed in situ during shearing, but from photochemical degradation of tribofilm induced by high-energy laser. Based on IR analysis, tribofilms were organic materials containing oxygenated groups. These results suggested surface oxygen was a reactant, which was also supported by the findings in simulation.

5E

11:30 am – 12:00 pm

3831621: Durability of Materials for Nanoelectro - mechanical Switches Studied by Scanning Probe Microscopy

Cangyu Qu, Robert Carpick, University of Pennsylvania, Philadelphia, PA

Nanoelectromechanical systems (NEMS) switches, a candidate for next-generation electronics for their negligible leakage and low operation voltage, suffer from poor reliability featured by various failure modes during cyclic operation. In this work, the durability of electrical contact materials is studied by scanning probe microscopy (SPM) under NEMS switch-like conditions, with the goal of understanding the tribo-electro-mechanical mechanisms leading to failure. We use an SPM-based methodology for high-throughput assessment of candidate contact materials, with a Pt/Pt interface studied as a prototypical demonstration. The evolution of interfacial properties is measured for millions to billions of contact cycles. The accumulation of insulating tribopolymers resulting from applied stress and bias to adsorbed airborne contaminants is investigated. Measurement on the tribopolymer growth rate and its dependence on contact stress supports a stress-assisted thermal activation model.

Session 5F | 103A

Contact Mechanics I

Session Chair: Shuangbiao Liu, Northwestern University, Evanston, IL

Session Vice Chair: Robert Jackson, Auburn University, Auburn, AL

8:00 am – 8:30 am

3831690: Understanding the Role of Contact Interfaces on Tribo-electrification in Triboelectric Nanogenerators

Charchit Kumar, Jack Perris, Satyaranjan Bairagi, Nikolaj Gadegaard, Daniel M. Mulvihill, University of Glasgow, Glasgow, United Kingdom; Yang Xu, Hefei University of Technology, Hefei, China

Triboelectric nanogenerators are an emerging technology to harvest electricity from mechanical energy, based on triboelectrification and electrostatic induction effects. In recent years, a large amount of research has been done in the field of TENGs, however the fundamental contact mechanics of TENGs is not clear yet. This work presents a systematic contact mechanics investigation on a simple and robust TENG device. Controlled roughness instances were numerically created and developed using 3D printing and replica-moulding procedure. Surface characterization results confirmed the accuracy of developed tribo-layers. A linear electrodynamic rig was modified to perform electro-mechanical tests, based on the contact-separation mode. Triboelectric and contact area measurements were carried out to investigate the influence of applied load and frequency. Electrical output results were correlated with surface topographies and were discussed regarding contact signatures and strain localization.

8:30 am – 9:00 am

3812297: A New Approach for Calculating the Contact Heat Transfer Coefficient Based on Real Component Surfaces

Patrick Wingertszahn, Stefan Thielen, Oliver Koch, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

The temperature profile between two adjacent components is of great importance in many technical applications. Therefore, the calculation of the thermal contact resistance is an essential element for the simulation of the heat transfer when two bodies are in contact, with or without an interlayer. According to the current state of the art, this important input parameter for thermal simulations is determined in experiments. Due to the large number of dependencies, these are very time consuming. In this approach, the heat exchange between two rough bodies in contact is calculated by iteratively solving the heat conduction problem with a multigrid method. Real component surfaces are considered to calculate the temperature distribution. The following parameters were investigated for their influence: surface roughness, contact pressure, temperature level and temperature difference. This model allows a fast prediction of these parameters by measuring the contact surfaces of both bodies.

9:00 am – 9:30 am

3808042: Tribological Issues in the Wheel-rail Interaction: Background and Experiences

Angelo Mazzu, University of Brescia, Brescia, BS, Italy

The wheel-rail system is subjected to a complex interaction of several damage phenomena, even in competition with each other. In clean and dry environment, the most frequent phenomena are ratcheting and wear, especially in sliding condition such as in curve or braking, which result in the formation of surface cracks. In presence of fluid contaminant, such as rain or snow, rolling contact fatigue often prevails, because the surface cracks are filled by the fluid, which is pressurized at every load pass and promotes their propagation. Solid contaminants, such as sand, induce severe abrasive wear, leading to excessive modification of the wheel-rail contact patch and low duration. Thermal loads, occurring in shoe braking operation or in excessive sliding, can lead to heating cycles, which alternate the material microstructure up to the formation of white etching layers (WELs). The experimental and computational experience of the University of Brescia in the study of these phenomena is presented.

9:30 am – 10:00 am

3810658: Identification and Analysis of Some New Influencing Parameters on the Surface Damage of Rolling Elements Bearings by a CEL Model

Amakoe Ahyee, Daniel Nelias, Thibaut Chaise, Arnaud Duval, INSA DE LYON, Lyon, Villeurbanne, France

In this paper, an investigation is carried out on the passage and crushing of particles between the rolling elements and the rings. During operation it very often happens that particles from various sources pass into the contact between the rings and the rolling elements bearings. This results in the formation of dents which can cause damage. To model this phenomenon, some authors have adopted finite element modeling [1-2]. Recently in 2019 a CEL model developed by Bonetto et al. [2], was able to reproduce and analyze the crushing of particles on the surfaces. Thus, they identified some first-order parameters that influence the geometry of dents such as: debris size, Hertzian pressure, friction coefficient, material properties, and relative sliding between the surfaces. A parametric study conducted with an upgraded CEL model has allowed us to identify some new first-order parameters such as: particle shape, particle location in the contact, and the presence of a critical sliding rate.

10:00 am – 10:30 am – Break

10:30 – 11:00 am

3816862: Investigating the Contact Area Reduction Over a Nearly Complete Rough Surface Spectrum

Robert Jackson, Auburn University, Auburn, AL; Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

This study investigates the predictions of the real contact area for elastic and elastic-plastic rough surfaces using a 'nearly complete' surface spectrum for a real surface using a multiscale and statistical model framework. The spectrum employed characterizes the surface dow to the nanoscale. The results show that even the smallest scales can have a significant influence on the contact area, especially when the contact is elastic. However, when the contact is elastic-plastic, the influence of smaller scales can be limited depending on the structure of the surface's spectrum. If the spectrum shows a self-similar trend at some scales, then the pressure tends to saturate at those scales. This work also explores the inclusion of scale dependent yield strength, since it will vary with the scale of the asperities.

11:00 am – 11:30 am

3847781: Contact Mechanics of the Patterned Surfaces Generated by Spinodal Decomposition and Amplified Instability

Wonhyeok Lee, Melih Eriten, University of Wisconsin-Madison, Madison, WI

Recent techniques employing dynamic evolution of microstructures (spinodal decomposition) and instabilities amplified via centrifugal acceleration offer viable and cheaper alternative ways to micromanufacture functional patterned surfaces. When interfacing those patterned surfaces with other components and under self-contact scenarios, geometric variability can cause stress concentration and abrupt failure around the contact. We investigate numerically the real area of contact, contact pressures and stress concentration factors of patterned surfaces formed by spinodal decomposition and amplified instabilities. We first generate patterned surfaces in congruence with actual surfaces created by those processing techniques. Then, we conduct normal-contact analyses of those surfaces via boundary element method under nominal mean pressures ranging from (0.001-1) E*, where E* is the contact modulus. To account for the influence of the processing parameters, we also perform a parametric study.

11:30 am – 12:00 pm

3847744: A Numerical Model for Simulating the Transient Frictional Viscoelastic Sliding Contact

Dongze Wang, Ali Ghanbarzadeh, Greg de Boer, Institute of Functional Surfaces, Leeds, United Kingdom

The problem of sliding contact has always been an area of interest to determine the behavior of viscoelastic materials in practice. Considering that there exists little literature reporting the effects of the partial slip regime on the later sliding contact solutions, a frictional viscoelastic sliding contact model is developed in the study, where transient solutions showing the whole evolution from partial slip to gross slip are available. Results show that though the partial slip regime causes a trivial change in normal pressure distribution (e.g., lower peak pressure), it delays the time required by viscoelastic surfaces to reach their steady state. This suggests that the frictionless assumption (no dry friction), which is adopted in most numerical and theoretical models, could induce quantitative differences when analyzing sliding contacts of viscoelastic materials. Qualitative errors may even be encountered when the observation time is too small to capture the actual steady state.

Session 5G | 103B

Tribotesting I

Session Chair: Md Hafizur Rahman, University of Nevada, Reno, Reno, NV

Session Vice Chair: Soumya Sikdar, University of Nevada, Reno, Reno, NV

8:00 am – 8:30 am

3831949: Physicochemical and Tribological Comparison of Bio- and Halogen-Based Ionic Liquids

Md Hafizur Rahman, Tatianna Macias, Manoranjan Misra, Pradeep Menezes, University of Nevada, Reno, Reno, NV; Ting Liu, Ashlie Martini, University of California, Merced, Merced, CA; Manish Patel, ExxonMobil, Austin, TX

Phosphonium-based ionic liquids (P-RTILs) have received significant attention recently for lubrication applications due to their physiochemical and tribological properties. Bio-derived P-RTILs are of particular interest for environmental sustainability. In this investigation, we characterized and compared the physicochemical and tribological properties of bio-based trihexyltetradecylphosphonium saccharinate [P-Sacc] and halogen-based trihexyltetradecylphosphonium bis(trifluoromethylsulfonyl)amide [P-NTF2] ionic liquids between 10-120°C to understand their thermal stability, wettability, rheology, as well as lubrication and corrosion mechanisms at steel sliding interfaces. [P-Sacc] has comparable thermal stability, higher viscosity, and higher density than [P66614] [NTF2]. The higher viscosity and stronger cohesion of [P-Sacc] contributed to its ability to form an effective adsorption film that reduced friction and wear more than the halogen-based IL across the range of temperatures.

8:30 am – 9:00 am

3816669: Experimental Analysis of Pasting of Brushed DC Motors

Roman Dzhafarov, Daniel Braun, Stephan Diez, Joerg Kopitzke, BMW AG, Munich, Germany

Modern automobiles are equipped with many components in which DC motors are used. A possible failure mechanism in case of brushed DC motors can be so-called pasting. While operating of DC motor some carbon brush debris accumulates in the commutator's insulating air gaps. It clogs the slots with conductive carbon paste resulting in a loss of insulation resistance between the commutator segments. This phenomenon affects the motors efficiency and finally triggers the failure of the electric motor. The significant influencing parameters of this process are humidity, load regimes and the composition of the carbon brushes. The aim of this work is to derive the scientific understanding of the physical and contact mechanical phenomena behind the process of pasting as well as to show the interactions between the commutator, carbon and the used lubricants by different environmental conditions.

9:00 am – 9:30 am

3805962: Another Approach to Tribotesting – Enabling AI

Dirk Drees, Lais Lopes, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Emmanouil Georgiou, Hellenic Air-Force Academy, Dekelia Air Force Base, Athens, Greece

AI applications are in the news, so also in our field of tribology, eyes are turning to this powerful technique; how can we discover new insights? The limitation today is the lack of enough relevant and reliable data to train AI systems. Wear resistance particularly, is a parameter with large variability, so relevant data requires typically long tests and many repeats. Our approach to generate data at affordable cost, is using multi-station

wear testers. This causes a paradigm shift in tribology – we no longer use sophisticated tribometers to analyze a single test but want to generate statistical data and use automatic data collection and analysis. We are showing our concept of data collection and the prototype parallel wear device with its first results.

9:30 am – 10:00 am

3812432: Measuring Lubricant Viscosity Under Shearing In Situ Using Ultrasound

Gladys Peretti, Rob Dwyer-Joyce, University of Sheffield, Leeds, United Kingdom; Nathalie Bouscharain, Fabrice Ville, Insa Lyon, Lyon, France; Fabio Tatzgern, Nicole Doerr, AC2T research GmbH, Wiener Neustadt, Austria

Sliding machine parts can lead to elevated temperatures, extreme pressures, and high shear rates. Shearing a lubricant modifies its properties, such as viscosity, which is a critical parameter to ensure proper lubrication and operation. Ultrasound has been used to measure lubricant film thickness, but this technology is relatively new for viscosity measurements. Therefore, the aim of the study is to determine lubricant viscosity under shearing using ultrasonic transducers. A signal processing approach is established to determine oil viscosity based on reflected ultrasonic signals. The results of ultrasonic measurements are compared with those obtained with a rheometer. Beside shearing, the impact of several parameters on viscosity is also discussed: base oil chemistry, fresh and used lubricants, temperature, lubrication gap.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3817410: A Simulated Test Methodology for Screening of Friction, Wear, and Extreme Pressure Properties of Hydraulic Oils

Rajendra Mahapatra, Indian Oil Corporation Ltd. R&D Centre, Faridabad, Haryana, India

Lubricating oil in hydraulic systems performs dual functions of lubrication and transmission of power. Oil contains necessary additives to ensure AW characteristics, proper viscosity to maintain adequate sealing and lubrication. It is difficult to simulate the AW characteristics of a vane pump in a bench top tribometer. This paper describes a simulation of the frictional, wear and EP characteristics of hydraulic fluids using a SRV machine by analyzing friction coefficient, wear scar, and analysis of tribo-pair. The load carrying capacity having indicative of EP characteristics was also studied using a SRV load stage test. To validate the SRV results, performance testing on an Eaton 35VQ25 vane pump test as per ASTM D6973 was carried out on the test fluids. The studies indicate a correlation of the pump test performance with the frictional, wear and EP characteristics. A simulated test methodology for quick screening of friction, wear, and EP properties of hydraulic oils has been developed.

11:00 am – 11:30 am

3806602: Measuring the Damping Capacity of Oils

Kenneth Budinski, Bud Labs, Rochester, NY

There are at least a dozen ASTM standards for measuring and comparing the friction responses of different oils in specific test rig tribosystems. However, these tests do not address the retarding force on a crankshaft sloshing through an oil sump. This is attritious friction. It is the retarding force or damping on a solid moving through a fluid such as oil. The damping capacity test uses a swinging pendulum made from a metal rod set into motion and the end is immersed to a given depth in the test fluid. The relative decay of the pendulum motion in the test fluid is the test metric. Tests were conducted on four commercial oils with the same listed viscosity at temperatures from 70C to 1000C. In all cases, there were significant attritious friction differences between supposedly the "same" oil. This is a new "fluid friction" test, and work to date suggests that it simulates energy losses caused by fluid retardation, better than viscosity tests.

11:30 am – 12:00 pm

3813143: Effect of Environment on Fuel Lubricity Standards

Stephen Berkebile, Monica Ferrera, Briana Segal, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Fuel lubricity has a large impact on system wear in mixed and boundary lubrication conditions found in high pressure fuel pumps, however lubricity standards do not simulate fuel pump environments nor reproduce observed pump damage. ASTM Standard D5001 Ball-on-Cylinder Lubricity Evaluator (BOCLE) is used for evaluating lubricity of aviation turbine fuels, and ASTM D6079 High-Frequency Reciprocating Rig (HFRR) is used for diesel fuels. Scuffing Load BOCLE (SLBOCLE) measures scuffing failure in severe conditions in diesel fuels. All are conducted in air rather than the low-oxygen environment found in fuel pumps. We compared the three standards in both air and an oxygen-starved nitrogen gas environment for over ten fuels. We observed differences in wear and fuel ranking due to the presence/absence of oxygen on fuel lubricity measurements for all fuels. We compare the three testing methods and discuss the reasons for the differences based on microscopy and spectroscopy of the wear scars.

Session 5H | 103C

Commercial Marketing Forum V

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:30 am

3908345: ExxonMobil – Empowering the World's Lower Carbon Ambitions Through SpectraSyn™ PAO Basestock Technology in Industrial Lubricant Solutions

Lindsey Bunting, ExxonMobil, Spring, TX

For over a century, lubricants have been essential for efficient operation of machines that are critical for modern life. As the world pursues a lower carbon future, synthetic base stocks can play a significant role in helping to improve both energy efficiency and productivity. Industrial lubricants based on SpectraSyn™ PAO technology can unlock not only a reduced total cost of ownership versus mineral-based incumbents, but also increase energy efficiency and therefore reduce associated energy consumption. In this presentation, we will discuss the market trends and conditions leading towards the increased adoption of synthetic-based industrial lubricants along with examples illustrating the economic and efficiency/durability benefits of designing synthetic industrial lubricants using SpectraSyn™ PAO technology. To support our customers and the industrial lubricants market, ExxonMobil is dedicated to creating solutions that improve quality of life and meet society's evolving needs.

8:30 am – 9:00 am

3909566: ExxonMobil – SpectraSyn™ MaX PAO Technology for Next Generation Electric Vehicle Driveline Fluids

Michael Toohey, ExxonMobil, Spring, TX

Market studies predict significant growth of alternative powertrain vehicles (PHEV, BEV, FCV) as part of the global vehicle fleet by 2050. The emergence of these alternative powertrain electric vehicles (EVs) plus the persistent trend towards lower viscosity fluids create new challenges for fluid formulators. ExxonMobil Product Solutions continues

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Monday 22 May | 4:30 - 5 pm
Session: Metalworking Fluids II
Title: Sustainability Beyond Carbon Footprint

Tuesday 23 May | 4 - 4:20 pm
Session: Commercial Marketing Forum
Title: Solutions for today's metalworking and cleaning formulations

Thursday 25 May | 8 - 8:30 am
Session: Metalworking Fluids V
Title: Advances in Bio-Based Metalworking Fluids – Addressing Formulation Challenges by Balancing the Use of Additives

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INDUSTRIAL FLUIDS & LUBRICANT

to innovate with unique step-out base stocks to enable high performance fluids for these EVs. This presentation details the benefits of the innovative SpectraSyn™ MaX PAO technology platform providing improved performance properties compared to conventional low-viscosity PAOs. SpectraSyn™ technology can be incorporated in formulations designed to meet the drivetrain requirements of second generation EVs and can help deliver improved EV energy efficiency while maintaining excellent protection and durability over the vehicle lifetime. SpectraSyn™ technology may also help improve thermal management of the e-motor and power electronics.

9:00 am – 9:30 am

3911531: Advanced Chemical Concepts – The Design and Development of High Performance Metalworking Lubricant and Rust Preventatives

Matthew Roberts, Advanced Chemical Concepts, Strongsville, OH

Water extendible multi-metal lubricity additives: Multi-functional lubricity additives used in many high performance machining applications. Easily formulated in low oil semi-synthetic and high oil semi-synthetic fluids they are highly effective in all types of machining of aluminum, steel, titanium, magnesium and other alloys.

Rust preventives: The timely introduction of rust preventives will fill an urgent need in the market. Used in solvent/oil they provide excellent metal protection in humidity testing, salt fog testing and water displacing. Steady and reliable supply are ensured.

9:30 am – 10:00 am

3909401: The Lubrizol Corporation – Innovative Corrosion Inhibitor for Metalworking and Industrial Applications

Gabe Kirsch, The Lubrizol Corporation, Wickliffe, OH

Ferrous corrosion control continues to be a dominant need in both metalworking and other industrial applications. Oil marketers need corrosion inhibitors meeting challenging performance requirements, as well as enhanced solubility and registration requirements. A desired corrosion inhibitor should therefore address these aspects and be versatile across multiple end-uses. To provide an inhibitor to oil marketers with these value-added properties, Lubrizol has launched LUBRIZOL® IC9RTD2, a ferrous corrosion inhibitor for oil-based products. Based on proprietary technology, IC9RTD2 provides not only excellent corrosion inhibition and base oil solubility – as well as broad regulatory acceptance – but also other performance qualities that extend its applicability beyond metalworking into other industrial market purposes. This presentation will share the benefits of IC9RTD2 that can be gained in your oil-based products.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3811520: Solvay's Solutions for Sustainable Lubricant Additives

Julie Mollet, Solvay, Princeton, NJ

At Solvay, we believe that finding solutions to humanity's biggest challenges requires scientific breakthroughs that protect our heritage for generations to come. Solvay One Planet turns our ambition into concrete actions. It ensures that we focus our efforts on the areas where our innovation and sustainable solutions can have the biggest positive impact, directly and indirectly, in line with the UN Sustainable Development Goals (SDGs). This presentation will focus on Solvay's One Planet ambition and deep dive on our solutions for Metal Working Fluid with our low eco-toxicity for operations such as cutting and hot rolling and our solutions for Electric vehicles with our range of resilient, anti-wear and extreme-pressure (AW/EP) lubricant solutions for EVs.

11:00 am – 11:30 am

3824034: LANXESS Deutschland – A New VOC-Free Temporary Corrosion Inhibitor, Bt Diluted in Water – A Contradiction?

Wilhelm Rehbein, Isabell Lange, LANXESS Deutschland GmbH, Mannheim, Germany

Corrosion turns out to be of even higher significance during the last decades. In a globalized world, transportation of parts by road or oversea becomes even more important, but also indoor and outdoor storage is still significant. The economic damage that is caused by corrosion shows quite impressive numbers, though effective rust preventatives are still of highest importance. Nowadays rust preventives based on organic solvents or mineral oil are widely spread and their application is well known. However, products that contain VOC are getting into a focus concerning health and environmental issues. Due to stricter guidelines and regulations, it becomes crucial to develop products that are better adapted to environmental specifications. With Additin® E555, a rust preventative package was developed that is used with water as "solvent." Its new VOC-free technology is in alignment with the latest trends towards sustainability and less impact to human health and the environment.

11:30 am – 12:00 pm

3909389: Functional Products – Continued Innovation with Novel Tackifiers for Unique Base Stocks

Mike Woodfall, Functional Products, Macedonia, OH

Tackifiers are a special class of polymer-based lubricant additives which impart tack or string to lubricants. This quality is required to: control the fling off and misting of lubricants in high-speed applications; control cleanliness in operation; and tailor the adhesive/cohesive properties of a lubricant or grease for its application in the field. Functional Products Inc. has been an innovative developer of specialty tackifiers and other polymer-based lubricant additives for 37 years – including viscosity modifiers, pour point depressants, components, and packages. This talk will showcase examples of our work in developing new polymer technologies (tackifiers, for instance) for unique and novel lubricants in various non-standard base fluids. Functional Products seeks to be your development partner on new opportunities for lubricant and grease formulation projects. We do the search so you can do the research.

Session 5I | 104A

Electric Vehicles V

Session Chair: Christopher Cleveland, Afton Chemical Corporation, Richmond, VA

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

8:00 am – 8:30 am

3926728: Cooling and Lubrication Efforts of Tesla Drive Units and Tesla's Perspective of Future Electric Vehicle Lubricant Development

Wenyang Zhang, Tesla, Inc., Palo Alto, CA

Lubricant formulation design, lubrication design, and cooling architecture are critical for drive unit performance and durability. OEMs are currently adopting mechanical designs for electric motor cooling and gearbox lubrication. It is a popular option of pushing for lower fluid viscosity and cost efficient raw materials to further achieve cooling efficiency, energy efficiency, and build cost while it is not necessarily lowering overall system cost especially factoring the vehicle lifetime performance, maintenance, and overall energy cost. Based on one of the

Tesla's driver unit design, author break down Tesla's approach on solving complexity of electric vehicle lubrication and lubricant design, in terms of optimal fluid design, viscosity tuning, and meeting durability requirement. Energy efficiency breakdown of drive unit is discussed as it closely related to lubricant and lubrication design. Authors also discuss Tesla's perspective on the future electric vehicle lubricant development.

8:30 am – 9:00 am

3833980: A Study of the Effects of Foam and Antifoam Performance in Electric Vehicle Base Fluids

Safia Peerzada, Munzing 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.

9:00 am – 9:30 am

3830293: Extrinsic Sustainability Benefits of Esters Suitable for Use in Electric Vehicle Gear and Battery Cooling Systems

Bethan Warren, Gareth Moody, Chris Clayson, Cargill, York, United Kingdom

Fluid technology for electric vehicles is developing at a rapid rate with fluids which can aid range extension and fast charging being of particular significance. This presentation will give an overview of the intrinsic sustainability benefits of using esters as part of the formulation as well as a comprehensive review of the extrinsic benefits (reducing CO_2 in use) covering aspects such as efficiency boosts, thermal capabilities and material compatibility as well as introducing a new, very low viscosity base fluid suitable for both gear lubricant and direct battery cooling applications.

9:30 am – 10:00 am

3812488: Study on the Impact of Dedicated Electric Drive Fluid Properties on Total Efficiency of Drive Unit

Pedro Cawich, Masato Yokomizo, Scott Rajala, Idemitsu Lubricants America Corporation, Wixom, MI; Hiroyuki Tatsumi, Idemitsu Kosan Co., Ltd., Ichihara-shi, Chiba, Japan

Recently with increased concerns and regulations for the environment, it has become critical to reduce energy loss in many fields. Hence, many OEMs have invested heavily in developing new electric motors with innovative designs. Common ATFs keep being the preferred fluids for these new motors although new and more severe requirements are needed. New electric motors require for improved cooling performance by the oil to increase total efficiency which common ATFs cannot provide. Reducing the viscosity and improving the thermal conductivity of the oil can be effective ways to improve cooling performance but their effects on total efficiency have not been clarified. In this study, the impact of viscosity and thermal conductivity on total efficiency were investigated using a formulation designed for an electric drive unit.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3813071: Fine Tuning the Structure of Esters to Optimize Their Properties as e-COOLANTS

Siegfried Lucazeau, NYCO, PARIS Cedex, France

Fluids and lubricants used in electrified vehicles need specific features in the case of direct cooling (battery, engine or e-axle fluids). Synthetic esters do show several benefits in such applications. They give access to ultra-low viscosity whilst keeping a higher level of fire safety than other base fluids. They also show very good thermal conductivity levels, an improved resistance to oxidation, and a remarkable ability to reduce traction. However, esters also show some limitations that must be considered. Synthetic esters are flexible, tunable compounds; a detailed understanding of the relationship between chemical structure and properties allows us to design the optimum fluids and find the best tradeoff between sometimes conflicting features. Practical examples of balancing properties of esters lead to improved elastomer compatibility of a given fluid, as well as optimized traction reduction, whilst maintaining excellent heat dissipation and fire safety features.

11:00 am – 11:30 am

3831897: Shear Stable Ester Thickeners – EVs and Beyond

David Gillespie, Kevin Duncan, Cargill, Snaith, East Yorkshire, United Kingdom

Protecting gears from wear can be achieved using high viscosity thickening additives, traditionally based on petrochemical ingredients. Equivalent formulations based on renewable resources are desirable to enhance the environmental profile of finished gear oils. High molecular weight (Mw) esters can be used as alternative thickeners, with benefits of improved film formation and thickening efficiency. High Mw thickeners tend to exhibit poor shear stability, and this generally scales with Mw. Formulating gear oil transmission fluids for electric vehicles therefore offers a particular challenge, where gear rotational speeds are expected to exceed 30k rpm. Design of experiments methodology is used to accelerate product development and find an optimal balance between thickening efficiency and shear stability. This analysis is then used to develop a shear stable, efficient thickener, with an excellent sustainability profile that will enhance the performance of gear and transmission fluids.

11:30 am – 12:00 pm

3889256: eTribology — Electrification of and Initial Results from the Mini Traction Machine

Peter Lee, Carlos Sanchez, Andrew Velasquez, Southwest Research Institute, San Antonio, TX

With the increase in Electric Vehicles comes the opportunity to optimize lubricants for these electrified drivelines. Southwest Research Institute tribology labs have electrified a block-on-ring test rig and shown there to be a noticeable change in wear and friction response when operated under an electric potential, both AC and DC current. To further study this phenomena, SwRI tribology labs have adapted a Mini Traction Machine (MTM) to electrically insulate test components and run them under electrical potential. The MTM is a well understood test that is commonly used for analyzing the friction and wear behavior of driveline lubricants. Introducing an electrical potential as a new test variable will present an opportunity to better understand e-driveline lubricants. This presentation will discuss the theory and initial results.

Session 5L | 201B

Surface Engineering I

Session Chair: Ali Beheshti, George Mason University, Fairfax, VA

Session Vice Chair: Sougata Roy, University of North Dakota, Grand Forks, ND

8:00 am – 8:30 am

3869732: Part-to-Part and Machine-to-Machine Variability in Roughness and Corrosion Properties of Additively Manufactured Stainless Steel

Peter Renner, Michael Melia, Erin Karasz, Kasandra Escarcega Herrera, Michael Heiden, Jeffrey Rodelas, Sandia National Laboratories, Albuquerque, NM

Property variability for metal parts made by additive manufacturing (AM) techniques is a major barrier to their commercial insertion. Variability can arise from slight powder feedstock size distribution and chemical differences due to inherent process fluctuations and optimized parameter sets across different machines. How these multiple sources of variability influence roughness and corrosion behavior of AM metals is not fully understood. This presentation focuses on part-to-part and machine-to-machine variability for surface roughness and corrosion properties of a laser powder bed fusion (LPBF) 316L material. Six laboratories in the USA collaborated on analysis of the roughness variation of as-printed surfaces from the LPBF 316L material. The corrosion behavior showed some correlation to roughness variability, but other factors such as oxide surface coverage and composition play a major role.

SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525 SAND2022-17046 A.

8:30 am – 9:00 am

3812617: Tribological Behavior of Textured Surfaces Produced by Laser Powder Bed Fusion

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

Surface texture impacts 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 the texturing and additive manufacturing processes can be combined, parts thus made can be used in their as-built condition. Then production cost can be reduced, and a prolonged life of these parts can be expected. This work focuses on the directional dependence of friction and wear on the textures of as-built additively manufactured surfaces. Reciprocating tribotests are performed on the top surfaces of samples produced by laser powder bed fusion with the sliding direction parallel, perpendicular, and angled to the laser scanning direction. Friction and wear are evaluated with respect to the location in the track formed during experiment and correlated to velocity variation.

9:00 am – 9:30 am

3833013: Development and Performance Evaluation of Novel Surface Polishing Technique for Additively Manufactured Components

Kommineni Uday Venkat Kiran, Sougata Roy, University of North Dakota, Grand Forks, ND; Brady Kimbrel, NASA Marshall Space Flight Center, 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 metallic parts. DEMC uses the synergetic influence of mechanical and electrochemical functions of the polishing to reduce the surface roughness of AM. The process parameters, such as voltage and polishing time variation on the material removal rate, surface morphology, and surface roughness, were analyzed by comparing experimental and characterization results. Sample surface morphologies were analyzed using OM, non-contact surface profilometry, and SEM analysis. Sample surface chemical compositions were detected using EDS spectroscopy. Amplitude, spatial, and hybrid surface roughness parameters were investigated before and after polishing process. The reduced surface finish of metal AM components using this technique validates its capability to post-process metal AM components.

9:30 am – 10:00 am

3833893: Friction and Deformation of Additively Manufactured Micro/Nano-Hierarchical Structures with Different Structural Stiffness

Mahyar Afshar Mohajer, Min Zou, University of Arkansas, Fayetteville, AR; Xingwei Yang, Rong Long, University of Colorado, Boulder, Boulder, CO

Textures consisting of micro/nano-hierarchical structures are critical to realizing surfaces with functionalities such as superhydrophobicity. Understanding the tribology of such structures is of great importance. In this study, a small-scale additive manufacturing method known as two-photon lithography (TPL) was utilized to fabricate micro/nano-hierarchical structures (nanohair-covered micropillars). The accuracy and resolution of TPL enabled control over the stiffness of the structures by varying the nanohair length, and micropillar tapering angle. In-situ SEM tribological testing of individual micro/nano-structures provided direct observation of the effect of structural stiffness control on the onset of sliding motion, changes in the friction force, linearity of the relationship between the friction force and the applied normal load, and the interaction of the structures along different length scales.

10:00 am – 10:30 am – Break

10:30 am- 11:00 am

3833052: 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

Nitinol, an alloy made of Ni and Ti, has two special characteristics: shape memory and superelasticity. Due to its capacity to withstand significant elastic strains and superior mechanical properties compared to martensitic NiTi, austenitic NiTi alloys with superelastic behavior was studied for load-bearing applications. The microstructural characteristics and tribo-mechanical behavior of Nitinol fabricated via laser-wire directed energy deposition with superelastic NiTi wire was investigated, and the results were compared against that of cold rolled Nitinol. A set of systematic experiments including microstructure, hardness, porosity measurement, and thermal analysis via DSC were conducted.

Reciprocating sliding tests using a ball-on-flat type contacts, were performed in unlubricated conditions against steel balls at room temperature to 200°C. Decrease in friction coefficient with increasing operating temperature was observed in both additively manufactured and cold rolled Nitinol.

11:00 am – 11:30 am

3848291: Additively Manufactured Inconel 625 Subjected to Shot Peening and Laser Peening Processes: Microstructural and Elevated Temperature Fretting Wear Analyses

Ali Beheshti, Manisha Tripathy, George Mason University, Fairfax, VA; Keivan Davami, The University of Alabama, Tuscaloosa, AL; Lloyd Hackel, Curtiss Wright Surface Technology, Livermore, CA

Inconel 625 with excellent mechanical properties is highly used in harsh environments as joints, seals, valves, etc. With the rapid growth of the metal additive manufacturing industry, it becomes necessary to rigorously study the additively manufactured (AM) components trying to achieve comparable or even superior properties with reference to their conventional counterparts. This study showcases a detailed microstructural and surface property comparison between AM and traditionally manufactured Inconel 625 subjected to shot peening (SP) and Laser Peening (LP) processes. Surface morphology and mechanical properties as well as advanced characterization techniques like XRD, EBSD, and TEM were employed to collate the changes due to the different types of peening processes. In addition, the high temperature fretting wear properties of AM Inconel 625 and its wrought counterpart is evaluated at high temperatures up to 700 C.

11:30 am – 12:00 pm

3833036: Exploring the Wear Resistance of Additively Manufactured Al Parts for Future Lunar Exploration via Custom Developed Testing Strategies

Pial Das, Sougata Roy, University of North Dakota, Grand Forks, ND; Nicholas Dyrstad-Cincotta, Junior Nasah, Institute of Energy Studies, Grand Forks, ND

Erosion by high-speed abrasive particles is a major form of material degradation in numerous systems such as spacecraft, especially during landing on the moon or other planets. Additively manufactured aluminum alloy parts have several advantages over traditionally produced components, i.e., superior mechanical properties, and enhanced wear resistance. Reinforcement using select ceramics gives even higher strength, better wear behavior and higher density to Al matrix over conventional Al alloy by grain refinement and reducing dislocation movement. Unfortunately, most of the research has been done in the direction of the strength of the MMC while the erosion performance of those materials at extraterrestrial environment has not been extensively explored. In our recent work, we studied erosion performance of laser DED produced specimens under a simulated lunar environment and tested against lunar dust simulant particles impinging at high velocity, and varied temperature ranges.

Session 5M | 202A

Grease I

Session Chair: Victoria Parker, Sasol, Lake Charles, LA

Session Vice Chair: Salil Bapat, Purdue University, West Lafayette, IN

Session Starts at 8:30 am

8:30 am – 9:00 am

3803372: Role of the Grease Components on the Overall Frictional Response of a Greased Contact Subjected to Low-Sliding Velocity Conditions

Francesco Massi, Ilaria Ghezzi, Davide Tonazzi, Sapienza University of Rome, Rome, Italy; Cédric Le Coeur, Michael Rovere, Jeremy Chorier, SOMFY SAS, Cluses, France; Yves Berthier, Université de Lyon, INSA-Lyon, CNRS, Villeurbanne, France

Despite the use of lubricants has been promoted to reduce friction and guarantee an adequate life of components, lubricated contacts are not exempt from unstable vibrations, such as stick-slip. The presence of a lubricant introduces another parameter, which greatly influences the frictional contact response. In case of grease lubrication, the complex rheology of the grease, function of its different components (thickener, additives and oil), covers a key role by driving the frictional response as a function of the sliding velocity. Aiming to understand the role played by the different lubricant components, different types of lubrication conditions have been tested, corresponding to dry contact, oil lubrication and greased contact (with and without additives), both with and without Diamond-Like-Carbon solid lubricant. The results highlighted the relevant role of the thickener and additives that drive the overall frictional response of the greased contact pair under investigation.

9:00 am – 9:30 am

3814543: Unraveling the Role of Particle-Particle Contacts on Microscopic, Rheological and Tribological Characteristics of Nanoenhanced Greases

Jackson Uhryn, Leonardo Martin-Alarcon, Babak Soltannia, Aleksandra Govedarica, Milana Trifkovic, Philip Egberts, University of Calgary, Calgary, Alberta, Canada

Improving tribological properties and reducing the environmental impact of greases is of utmost importance. Nanoenhanced lubricants have been gaining popularity due to improved tribological performance. However, the physical mechanisms responsible in these complex systems is poorly understood. By using a model grease system consisting of organically modified nanoclay particles dispersed in base oil, we establish a link between the microstructure, rheological, and tribological properties. Further functionalization of clay platelets with oleic acid (OA) links particle-particle interaction, brittleness of network structure, network dynamics at high shear rates, and its effect on friction results. Imaging of these systems provides novel insights into the effect of OA on particle and steel interactions, friction, and rheology. Preliminary works on nanocellulose fiber systems, which have an alternative structure and stronger interaction than nanoclays, have shown similar promising results.

10:00 am – 10:30 am – Break

5M

10:30 am – 11:00 am

3831963: The Matrix Revisited: Exploration of Additive Choice with Different Thickener Types

Joseph Kaperick, Afton Chemical Corporation, Richmond, VA

The predominant matrix of choice for grease manufacturers has been lithium for several decades now. However, its position as the default for cost-effective, multipurpose grease formulations is beginning to show signs of weakening. The increasing imbalance in the supply/demand position of LiOH has inspired many grease manufacturers to evaluate alternate thickener types as options for a variety of applications. Unlike most lubricating oil formulations, additive interaction with the grease thickener matrix is a critical element that needs to be carefully considered to create an optimized grease formulation in an efficient and cost-effective manner. This paper looks at the impact of grease thickener type on additive selection by presenting the results of several studies and discussing theoretical aspects of the interactions in question.

11:00 am – 11:30 am

3834151: Ionic Materials in Greases: Influence on Lubrication and Electric Conductivity

Sergei Glavatskih, KTH Royal Institute of Tribology, Stockholm, Sweden

The use of ionic materials, such as ionic liquids, in lubricating greases opens new possibilities for tuning grease formulations for electric machinery and increasing lubrication efficiency. Ionic materials also bring new properties into lubricant design process that enable additional functionality. Their ionic nature facilitates ion-surface interactions promoting rapid growth of the friction and wear reducing boundary films. It is shown how architecture of non-halogenated ionic materials added to the greases influences their lubrication performance in the sliding and rolling contacts. Different thickeners are considered. Surfaces were analyzed by TOF-SIMS and other techniques. An approach to characterize conductivity of greases using electrical impedance spectroscopy is also considered.

11:30 am – 12:00 pm

3848545: OBCaS Grease Green One and Customized One

Guillaume Notheaux, Gautier Perrin, SEQENS, Porcheville, France

Benefits of OverBased Calcium Sulfonate (OBCaS) greases are well known in the industry and their manufacturing is well established. However, a specific process called "one-step process" is less known. Synthesizing directly OBCaS thickener under calcite form provides flexibility in choosing base fluid and ease of upgrade. Selecting 100% of the oil part contained in the final grease during the process offers many possibilities. For example, biodegradable OBCaS greases and easy oxidation improvement while keeping performances, biodegradability and label-free, solutions to replace completely Group I oils in the final grease; improved behavior under cold environment, thanks to new carriers, improved corrosion preventive under dynamic wet conditions, thanks to different co-acid and additives. A review of all possibilities and updated, with examples, will be presented.

Session 5N | 202B

Nanotribology V

Session Chair: Gokay Adabasi, University of California, Merced, Merced, CA

Session Vice Chair: TBD

8:00 am – 8:30 am

3819587: Understanding the Corrosion and Wear at Nanoscale Interface Using Machine Learning Technique

Ran Zhang, Saugat Tripathi, Ashutosh Pitkar, Miao Wang, Zhijiang Ye, Miami University, Oxford, OH; Yufei Wang, Hang Ren, University of Texas-Austin, Austin, TX

Tribological problems, such as wear and corrosion at the sliding interface, is an age-old problem that still costs US an estimated $20.6 billion annually. However, it is still lack of understanding of nucleation process of corrosion and wear due to the complexity and heterogeneity of properties on material surface and interface. The recent proliferation of novel machine learning (ML) algorithms has provided a unique opportunity to address the issue. In this study, we investigate initiation of wear and corrosion on metals using ML techniques. Both molecular dynamics (MD) simulations and experiments (including conductive atomic force microscopy (AFM) and scanning electrochemical cell microscopy (SECCM)) will be conducted to generate high-throughput synthetic data for machine learning training, validation, testing and prediction. Deep learning will be exploited to understand the causality between the microstructural features and the multiscale tribological properties.

8:30 am – 9:00 am

3833797: Frictional Behavior of Surfaces Textured with Various Core-Shell Nanostructures

Colin Phelan, Charles Miller, Josue Goss, Min Zou, University of Arkansas at Fayetteville, Fayetteville, AR; Robert Fleming, Arkansas State University, Jonesboro, AR; Christopher Rincon, Ronghua Wei, Southwest Research Institute, San Antonio, TX

The frictional behavior of aluminum (Al)/amorphous silicon (a-Si) and Al/diamond-like carbon (DLC) core-shell nanostructure textured surfaces (CSNTS) was studied using nanoindenters. The indenter tip size applied normal load, material type, deformation, and texture uniformity were found to have substantial effects on the frictional behavior. For both samples, the highest coefficient of friction (COF) occurred at the lowest normal load tested due to high adhesion forces. At low contact pressures, the Al/DLC CSNTS displayed a lower COF than the Al/a-Si CSNTS due to the superior tribological properties of DLC compared to a-Si. However, at higher contact pressures, the Al/a-Si CSNTS exhibited a lower COF because of better deformation-resistant properties of a-Si compared to DLC. The taller Al/a-Si core-shell nanostructures (CSNs) of the non-uniform Al/a-Si CSNTS interlocked with the indenter tip and deformed more severely than uniform CSNs, thereby leading to higher friction forces.

9:00 am – 9:30 am

3817233: Effect of Oxidation of Metal Surface on Additive Adsorption and Friction Property

Lin Sun, Tomoko Hirayama, Naoki Yamashita, Kyoto University, Kyoto-shi, Kyoto, Japan; Hironobu Nakanishi, Kobe Steel, Ltd., Kobe, Japan

To understand the friction characteristics of sliding surfaces, it is necessary to investigate the adsorption property of lubricant additives onto the sliding surfaces. The adsorption property depends not only on the type of metals and additives but also on the condition of the sliding

surface. Particularly, previous studies showed that the oxidization of metal surfaces significantly affects the adsorption property of additives, resulting in the change of friction characteristics. In this study, the nanotribological tests of metal surface in lubricant were conducted by using an atomic force microscope. To investigate the effect of surface oxidation to the friction characteristics, the top surface was previously worn by point-probe cantilever, and the nascent surface was exposed in lubricant. After that, the lubricant with additive was dropped respectively and the friction test was conducted in each area to check whether the friction properties differed due to the surface oxidization.

9:30 am – 10:00 am

3811486: Molecular Friction Models for Molecular Adsorbates

Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

Atomic-scale nanoscale friction models, based on ideas from Tomlinson and Prandtl, use simple periodic sliding potentials to model the velocity and temperature dependences of the friction force, for example, as measured in an atomic force microscope. However, this approach is not well suited to describing the friction of adsorbed molecular overlayers, for example, self-assembled monolayers (SAMs). We use a simple model interaction potential between the tip and the outer surface of the organic substrate to develop analytical models for molecular friction. This potential can be coupled to the molecular tilt to provide an analytical model for the chain-length dependence of SAM friction that is in good agreement with experiment.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3810952: Tribological Behavior of Graphene Quantum Dots as Novel Additives for Green Lubrication

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

Reducing friction, wear and saving resources are crucial for sustainable engineering, where tribology and lubrication can make a difference. Greener contacts with greener tribology are becoming a concern for new systems. One potential solution to the problem is nanotechnology with nanoparticles as additives to lubricants. In this work we studied the effect of graphene quantum dots (GQDs) mixed in aqueous glycerol in self-mated steel contacts. For comparison, the lubrication performance of aqueous glycerol with some other carbon-based materials, was also studied. The results show that the aqueous glycerol with GQDs provide excellent dispersion stability and significantly reduce the friction and wear. Mechanisms leading to this behavior are discussed in this work. We show that GQD-based green nano-lubricants have a great potential in sustainable engineering and should be investigated further for better insight into their active lubrication mechanisms.

11:00 am – 11:30 am

3833794: Probing the Mechanical Properties of Soot to Understand the Tribology of Contaminated Diesel Engine Oils

Alaaeddin Al Sheikh Omar, Institute of Functional Surfaces (iFS), Leeds , West Yorkshire, United Kingdom

The study has evaluated the role of modification in the crystal structure of soot in affecting the performance of engine oils [1-3]. Carbon black particles (CBPs) were used to simulate the real soot in the engine. Fully Formulated Oil containing CBPs was aged in the lab. The oils and CBPs were chemically investigated using FTIR, ICP, EDX and XRD. In-situ nano-compression tests for fresh and aged CBPs with different sizes were studied using SEM nanoindention. Nano-compression tests for single particle showed that aged CBPs had a higher deformation load to break the particle compared to fresh CBPs. The displacement load to deform the particles were increased to approximately double compared to fresh CBPs. This study demonstrates modification in the crystal structure, and how the ageing oil and interactions with additives can influence the turbostratic structure of soot, mechanical properties of particles and hence the tribological performance.

11:30 am – 12:00 pm

3909834: Failure Mechanisms of Two Nano Adhesives Based on MWCNTs and SiC Nanoparticles

Jayashree Bijwe, Indian Institute of Technology Delhi India, Nashik, Nashik, India

Several high-performance polymers especially polyaryletherketone (PAEK), polyetheretherketone, and polyetherketoneketone are being explored with a variety of fillers for adhesive applications. Their functioning mechanisms depend upon the type, amount, size, and shape of particles/nanoparticles (NPs) and the matrix used to form the composite adhesives. Active functional groups in the matrix or fillers also play an important role in enhancing the LSS of the adhesives. The current study explored different adhesive mechanisms for adhesives filled with MWCNTs -(OH-functionalized and plain) and SiC (Silicon carbide) nanoparticles in PAEK using stainless steel adherends. The MWCNTs (with OH functionalization) bestowed the highest LSS of 23 MPa. The thermal and mechanical properties of adhesives and failure mechanisms were studied in depth.

Session 6A | 101A

Lubrication Fundamentals VI: Innovative Test Methods

Session Chair: Marc Ingram, Ingram Tribology Ltd., Carmarthen, United Kingdom

Session Vice Chair: Brendan Miller, Chevron Oronite Company, Richmond, CA

1:30 pm – 2:00 pm

3813027: Boundary Lubrication in an Inert Atmosphere – A New Route to Sustainability

Hugh Spikes, Jie Zhang, Janet Wong, Imperial College London, London, United Kingdom

The recent availability of nitrogen concentrators that filter O_2 from an air flow to provide an almost pure N_2 stream may make it feasible to blanket closed lubrication systems in inert gas, with obvious benefits to lubricant life and allowable operating temperature. However, this requires lubricant formulations that can provide low friction and protection against wear, scuffing and rolling contact fatigue in zero or very low oxygen atmospheres. Here we compare the lubricating properties of base oils and lubricant additive blends in a nitrogen atmosphere with their response in air. In nitrogen, the base oils very rapidly form protective carbon films on rubbed surfaces, resulting in much lower friction and wear than seen in air. It is found that some lubricant additives behave quite differently in the two atmospheres and the origins of these differences are explored and interpreted in terms of both carbon film formation and the presence or absence of iron oxide on the rubbing surfaces.

6A

2:00 pm – 2:30 pm

3833863: Differential Topography on the Challenges of Three-Dimensional Characterization of Tribofilms

Nicole Doerr, Viktoria Seidl, Georg Vorlaufer, Serhiy Budnyk, AC2T research GmbH, Wiener Neustadt, Austria

The chemical composition of tribofilms from zinc dialkyl dithiophosphate (ZDDP) has been verified by numerous studies. The growth of such tribofilms can be monitored cycle by cycle using atomic force microscopy. This work discusses a methodology for the three-dimensional (3D) characterization of tribofilms to get insight into the lateral distribution of tribofilm thickness based on 3D optical microscopy images. Therefore, wear scars were produced with an engine oil in an oscillating ball-on-disk contact. The workflow for data analysis comprises techniques well-known from computer vision like image preprocessing and template matching. Topography data sets taken before and after the removal of the tribofilm were compared and aligned to each other using an iterative point cloud matching process. Results were quantified and visualized in terms of film thickness distribution.

2:30 pm – 3:00 pm

3830022: Achieving Macroscale Superlubricity in Non-Polar Oil by Sacrificial Carbon Nanotube Coating

Chanaka Kumara, Michael Lance, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Achieving superlubricity is an efficient way of reducing friction and improving energy efficiency. We achieved macroscale superlubricity using sacrificial carbon nanotube coating under ambient environmental conditions. Notably, a coefficient of friction of 0.001-0.007 was achieved when a CNT-coated stainless-steel disk sliding against a M2 tool steel disk in boundary lubrication using only a drop of Polyalphaolefins base oil. Raman spectroscopy and electron microscopy analysis showed a formation of graphene/ graphene oxide-based tribofilm on both contact surfaces. Further, sustainable superlubricity was achieved up to 10 km or 11 days of continuous sliding. This superlubricity CNT coating is potentially applicable to solve a wide range of friction and wear issues.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3813470: Lubricating Properties of Volatile and Gaseous Fuels

Hugh Spikes, Jie Zhang, Tribology Group, Imperial College, London, United Kingdom; Matthew Smeeth, Clive Hamer, PCS Instruments, London, United Kingdom

There is growing interest in the use of highly volatile and even gaseous fuels to replace conventional gasoline and diesel in crankcase engines. Volatile hydrocarbons can burn cleaner and have lower proportionate CO_2 emissions than higher molecular weight hydrocarbon fuels, while carbon-free gaseous fuels may eliminate CO_2 emissions altogether. Just like gasoline and diesel these fuels must be pumped and injected into the combustion chamber and must thus possess sufficient lubricity to prevent wear and minimize friction of pump and injector systems. This presentation describes the use of a new, sealed high frequency reciprocating rig to measure both friction and wear properties of a range of volatile and gaseous fuels. Because it is a sealed system it is also able to study the lubricating ability of conventional gasoline and diesel and their blends with bio-components at higher temperatures and pressures than is currently possible.

4:00 pm – 4:30 pm

3839578: Inevitable Deviations in Surface Profile and System Vibration Determine Tribological Behavior

Nikolay Garabedian, Yulong Li, Johannes Schneider, Christian Greiner, Karlsruhe Institute of Technology, Karlsruhe, Germany

A surface profile, in most cases, is characterized via roughness and waviness parameters, which are considered simple and informative scalar quantities. Such quantitative indicators must be used during the surface finishing process, as reaching a completely flat surface is impractical, if at all possible. Similarly, manufacturing surfaces with the exact same surface topography is almost unachievable in practice, and consequently, inevitable deviations always exist (within a prescribed acceptable range). The mounting process and the mechanical vibration from the tribometer further compound to the complexity of the tribological interface. In this contribution, the surface profile, interface-induced oscillations, and mechanical vibrations were measured in a pin-on-disk tribometer. It was found that there is a non-obvious interplay of surface and system properties, which, when taken together, strongly correlate with friction and can be used to predict the locations of highest wear.

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Session 6B | 101B

Rolling Element Bearings VI

Session Chair: Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH

Session Vice Chair: Kushagra Singh, Purdue University, West Lafayette, IN

1:30 pm – 2:00 pm

3812999: Numerical Analysis for Tapered Roller Bearing in Relation to Roller Profile Based on Running-In Method

Renshui Cao, Yonggang Meng, Tsinghua University, Beijing, China

Tapered Roller bearings (TRB) are widely used under large radial and axial loads at heavy-duty operations, such as gas turbine engines, axle boxes of bogies, etc. One of the technical problems in TRBs is the existence of sharp spikes of the contact pressure in the vicinity of the two ends of the tapered rollers. The quasi-static model and the mixed lubrication model are established to analyze the influences of different axial profiles on a single tapered roller and on the whole tapered roller bearings. The results show that the optimized profile, based on the numerical running-in method, has immense advantages in terms of the asperity contact pressure uniformity and the elimination of end effect of stress concentration not only for a single tapered roller but also for the whole tapered roller bearings. In addition, effects of other factors on asperity contact pressure distributions are discussed, including radial load (Fr), rotation speed (N), and standard deviation of roughness (Rq).

2:00 pm – 2:30 pm

3819320: Efficient Residual Stress Quantification in M50NiL Bearing Steel

Daulton Isaac, Mathew Kirsch, AFRL Turbine Engine Division, Wright Patterson Air Force Base, OH; Teresa Wong, Adrian DeWald, Hill Engineering, LLC, Rancho Cordova, CA

In this work, efforts to apply advanced stress release methods of residual stress measurement, namely slitting and slotting, to a bearing steel are presented. The advantages of both techniques can be seen in low error estimates, higher stress-depth resolution, and faster acquisition time. The test article chosen was a flat disk of M50NiL, a widely used case-carburized bearing steel. XRD measurements from two sources were also obtained on the same part in an attempt to interrogate the repeatability of that method. Good agreement was obtained between all the measurements made as well as with previously published data. The investigation was continued by executing slotting measurements on bearing rings made from M50NiL. XRD was also performed on these same parts. The similarities and contrasts between the results of the two methods are discussed as well as the challenges in applying the slotting method to curved surfaces of a bearing steel.

2:30 pm – 3:00 pm

3810628: Prediction of Rotation of a Shrink-Fitted Cup of a Tapered Roller Bearing Under Thermal Loading

Victor Pinardon, Sébastien Morterolle, Daniel Nelias, INSA Lyon, Villeurbanne, France; Timothée Gentieu, Safran, Vélizy-Villacoublay, France

In some tapered roller bearing mountings, it is usual to shrink fit the cup of the bearing into the housing. However, high transient thermal loads can lead to a decrease in clamping when the cup and its housing do not have the same thermal expansion coefficients. Under these conditions, the cup may start to rotate in the housing due to the torque transmitted by the bearing. This rotation could strongly affect the bearing performance. This study aims at predicting the risk of cup rotation by comparing the operating torque of the tapered roller bearing and the loss of clamping between the cup and the housing. The bearing torque is calculated with an analytical model of the bearing. The evolution of the shrink-fit torque is computed with a transient thermomechanical model. Particular attention is paid to the application of a significant mechanical loading as when the inner ring experiences misalignment.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3808525: A Generalized Machine Learning Model for Bearing Fault Diagnosis

Ling Wang, Amirmasoud Kiakojouri, nCATS, Southampton, United Kingdom; Honor Powrie, GE Aviation, Southampton, United Kingdom; Patric Mirring, Schaeffler Technologies, Herzogenaurach, Germany

Intelligent fault diagnosis for rolling element bearings (REBs) using machine learning (ML) techniques can significantly increase reliability of industrial assets. One of the main issues has been the lack of training data and most importantly the ability of ML models to be used for applications without specific training data, i.e., generalization capability. This study develops ML models using input features obtained from a novel hybrid method, combining cepstrum pre-whitening and full-band enveloping. The results show that a two-stage ML model, trained by data from the I2BS project, can successfully classify bearing faults present in a number of literature databases, including the Case Western Reserve University data, without further training. The bearing types and operating conditions in literature databases are completely different from those in the training data, thus presents a generalized ML model with the potential to be used to monitor bearings for a wide range of applications.

4:00 pm – 4:30 pm

3799664: Performance Evaluation and Life Estimation of Cryogenic Ball Bearing from Accelerated Life Test Results

Yeongdo Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea, University of Science and Technology, Daejeon, Republic of Korea; Wonil Kwak, Yongbok Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea, University of Science and Technology, Daejeon, Republic of Korea

Cryogenic ball bearing is an important rolling element of cryogenic pumps such as LNG pumps, and rocket turbopumps. In order to ensure stability of cryogenic pumps, performance of cryogenic ball bearing that used for then must be guaranteed. Performance of ball bearing includes load capacity, dynamic stability, reliability, durability. In this research, cryogenic ball bearing test rig was presented and with this test rig, accelerated life test of cryogenic ball bearing was performed to evaluate performance and life estimation of bearing. The tests were performed until bearing fault occur. In order to accelerate degradation of bearing and to estimate L10 life, load was chosen as an accelerated stress factor. At two levels of severe stress condition, test was conducted, Performance was evaluated with friction torque measured from test bearing and cage whirling orbit according to stress level. And we analyzed L10 life of ball bearing at each stress level.

4:30 pm – 5:00 pm

3813109: Accelerated Life Time for Cryogenic Ball Bearing: Evaluation and Discussion of Tribological Phenomena with the Various Internal Clearance Design

Yongbok Lee, Wonil Kwak, Yeongdo Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea

The reliability of cryogenic bearings is closely related to pump stable operation and life expectancy shall be ensured to ensure the life of the LNG pump required in the industrial field. This study develops a test evaluation instrument that can evaluate the reliability of cryogenic bearings by simulating the operating environment of the submerged LNG pump and presents a method of evaluating the reliability and lifetime of bearings for cryogenic environments based on experimental research. The cryogenic bearings under extreme load conditions rather than pump operating conditions were experimented with to predict their lifetime under the pump operating conditions. The fault detection was identified through variable dynamic signals such as cage whirling orbit, bearing friction torque, the temperature of the test bearing outer race, motor current value, and the frequency analysis of sound level meter and acoustic emission were used to identify defects among the bearing elements.

5:00 pm – 5:30 pm

3812159: Diagnosis of Grease Condition Using Dielectric Spectroscopy

Shunsuke Iwase, Taisuke Maruyama, NSK Ltd., Fujisawa, Kanagawa, Japan; Satoru Maegawa, Fumihiro Itoigawa, Nagoya Institute of Technology, Nagoya, Japan

In rolling bearings, poor lubrication causes damage such as fatigue and seizure. One of the causes of lubrication failure is physical and chemical degradation of grease, but the detailed mechanism is not known. Dielectric spectroscopy is a promising method to determine the physical and chemical states of lubrication in rolling bearings. In this study, dielectric spectroscopy of grease was measured using a parallel plate electrode. Five parameters were derived by applying a set of theoretical equations to quantify the dielectric properties of grease. These parameters were found to change depending on the internal state of the grease such as thermal degradation, which means that lubricant condition monitoring could be performed without collecting grease from the practical bearings by applying AC voltage between the electrode, which are the ring and the ball.

5:30 pm – 6:00 pm

3856942: Analytical and Experimental Investigation of Roller Behavior in a Spherical Roller Bearing

Abbas Shafiee, Farshid Sadeghi, Purdue University, W Lafayette, IN

In this study, a novel test rig was designed and developed to investigate roller slip, tilt, and skew in a spherical roller bearing (SRB). The test rig utilized a double-row 22313 SRB and was designed to allow for direct visual access to each row. A high-speed camera was used to capture the motion and angular position of the various rollers. Successive frames captured from the videos were analyzed to determine roller slip, tilt and skew. The dynamic behavior of the rollers was then corroborated with a previously developed SRB dynamic bearing model. The experimental and analytical results indicate that the roller tilt angle increases with axial load, remains constant with speed, and decreases with increasing radial load when the roller is located in the load zone. Further, roller skew in the load zone increases with axial load and shaft speed; however, it decreases with the radial load.

Session 6C | 102A

Synthetic Lubricants and Hydraulics I

Session Chair: Ryan Fenton, BASF Corporation, Tarrytown, NY

Session Vice Chair: Lauren Huffman, Dow Chemical, Midland, MI

1:30 pm – 2:00 pm

3812992: Liquid Amides – Novel, High Performance Base Oils

Claire Ward, Cargill, Goole, East Yorkshire, United Kingdom

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

2:00 pm – 2:30 pm

3812460: Synthetic Esters with The Advent of Electric Vehicles (EV) Era: Electric Power Factor & Heat Capacity, Structure-Property-Performance Relationships

Hoon Kim, Michael Creamer, Doug Placek, Zschimmer Schwarz US, Gordon, GA

With the advent of EV era technical focus of lubricant industry is in shifting from engine oil to ATF/driveline lubricants, and likewise from hydrodynamic lubrication to EHL/mixed lubrication in tribology. Since most electric cars run on compact battery with high energy density under high-speed, high-load and high-temperature environment, EV lubricants require desirable electrical properties, low traction, better stability, and better thermal control. Along this line, in this presentation we report our latest investigation on useful structure-property-performance relationships of various synthetic esters in terms of the effect of their chemical and viscometrical properties on thermal control and the electrical stability performances.

2:30 pm – 3:00 pm

3834140: Ionic Lubricant Design Considerations

Sergei Glavatskih, KTH Royal Institute of Tribology, Stockholm, Sweden

The lubricant design process requires availability of a wide range of molecular building blocks. Ionic liquids, materials composed entirely of ions but liquid under the conditions used, significantly expand the range of available species. As lubricant additives, ionic liquids are expected to primarily follow the surface adsorption mechanism for friction reduction. However, this process is strongly affected by the oil or grease type used to prepare an ionic lubricant. To show the differences we compare phosphonium ionic liquids with orthoborate and phosphate anions in terms of their interfacial film formation, both physisorbed and sacrificial from chemical breakdown, in sliding and rolling contacts. Analysis of the obtained results reveals how contact conditions and ionic liquid carrier chemistry influence lubricating functionality of the ionic lubricant.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3832052: Sustainability – "Energy Savings are Just an Oil Change Away"

Brian Hess, Evonik Oil Additives USA, Inc., Horsham, PA; Denis Sepoetro, Evonik Operations GmbH, Darmstadt, Germany

As climate change is one of today's biggest challenges, energy savings have become a primary target for equipment manufacturers and end users. Life Cycle Assessments (LCA) of energy efficient lubricants compared to currently established fluids quantify the effects an oil change can have on the carbon emissions along the entire life cycle of any machinery. Besides identifying the hotspots in the life cycle, strategies to reduce the Product Carbon Footprint (PCF) of the lubricant itself will be highlighted. The results demonstrate that switching to a high-performance lubricant significantly improves the sustainability performance of stationary and mobile hydraulic equipment, compressors, and industrial gearboxes. Furthermore, a lubricant upgrade is one of the most cost-effective and easiest measures to implement.

4:00 pm – 4:30 pm

3833575: Technical and Scientific Perspective from Using Polyglycol on a Composition of Compressor Lubricants

Eduardo Lima, Dow Chemical Brazil, São Paulo, Brazil

The perspective in seven dimensions attributed to Polyglycol being a differentiated technology of high performance for compressor system in fully formulated lubricants. In this presentation, perspectives from the Polyglycol synthesis process to the technical attributes related to this application will be explored.

4:30 pm – 5:00 pm

3819310: Testing Results of a Novel Bio-Based Oil-Soluble PAG Base Fluid and its Comparative Analysis to Conventional Oil-Soluble PAGs

Marlon Lutz, Biosynthetic Technologies, Indianapolis, IN

Polyalkylene glycol (PAG) lubricants have shown great promise and results as lubricants for many years and in many metalworking applications and offer many performance benefits. PAGs are polyether molecules that can vary in size and viscosity and generally are polar base fluids that provide affinity to metal surfaces generating suitable film strength properties for metal working applications. Common PAGs are produced from non-renewable resources which can impact end users who are striving toward better sustainable practices. At Biosynthetic Technologies, we have developed a renewable and bio-based oil-soluble PAG with exceptionally high bio-content and hydrolytic stability. We will discuss the physical and performance testing results of Biosynthetic's novel oil-soluble PAG and compare to commercially available oil-soluble PAGs on the market.

5:00 pm – 5:30 pm

3829733: An Investigation of Varnish Formation and Removal in a High Pressure Piston Pump

Shriya Reddy Kalijaveedu, Paul Michael, Milwaukee School of Engineering, Milwaukee, WI; Nathan Knotts, Zefu Zhang, Chevron Lubricants, Products & Technology, Richmond, CA

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 compared. A modular plate and frame heat exchange was used to facilitate the inspection and analysis of deposits. Fluids with high-varnish forming tendency deposited oxidation debris on heat exchanger and reservoir surfaces. Analysis of the debris revealed high concentrations of additive elements. A varnish removing additive was blended into the fluid and its effectiveness was evaluated at 50°C and 80°C. 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.

5:30 pm – 6:00 pm

3872834: Temperature-Dependent Density and Viscosity Prediction for Hydrocarbons: Machine Learning and Molecular Dynamics Simulations

Pawan Panwar, Milwaukee School of Engineering, Milwaukee, WI; Quanpeng Yang, Ashlie Martini, University of California, Merced, Merced, CA

Base oils used in the formulation of lubricant products are complex hydrocarbons of varying sizes and structures. This study developed Gaussian process regression-based models to accurately predict the temperature-dependent density and dynamic viscosity of 305 complex hydrocarbons. The presented approach provides versatile machine learning-based models with relatively simple and fewer predictors. In addition, an open-source python tool, PyL3dMD, was developed to calculate nearly 2000 dynamic (3D) descriptors from molecular dynamics simulations. It was found that the models developed using a small pool of dynamic descriptors performed similarly in predicting density and viscosity than models based on many more static descriptors. The best models predicted density and dynamic viscosity with R-squared values of 99.6% and 97.7%, for all data sets, including a test data set of 45 molecules. Finally, model-agnostic interpretation identified important predictors of density and viscosity.

6:00 pm – 6:30 pm

Synthetic Lubricants and Hydraulics Business Meeting

Session 6D | 102B

Materials Tribology VI

Session Chair: Morgan Jones, University of California, Santa Barbara, Santa Barbara, CA

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3859389: An Investigation into Wear of a Metal-Metal Interface in a Jet Engine

Mary Makowiec, Elizabeth Miller, Michael Fox, Pratt & Whitney, East Hartford, CT

Exit guide vanes are positioned at the aft end of the low-pressure compressor in a jet engine. These vanes direct the flow of air leaving the compressor to promote maximum efficiency. A recent evaluation of an engine-run part was performed to analyze and characterize the wear occurring on the support tabs of the outer diameter shroud of an exit guide vane. This presentation will discuss the outcomes of the analysis, including types of wear observed on the surface and characterization techniques used to evaluate the wear, including white light interferometry, scanning electron microscopy and elemental analysis, and x-ray photo spectroscopy.

2:00 pm – 2:30 pm

3812631: Formation of Wear-Protective Tribofilms on Different Steel Surfaces During Lubricated Sliding

Arman Khan, Tobias Martin, Jannat Ahmed, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Alloying elements in steels impact friction and wear behavior. We performed reciprocating tribotests on 52100 ball-on-steel flats with different compositions, heat-treated to similar hardness and microstructure, with polyalphaolefin and n-dodecane as lubricants. There are significant variations of friction coefficient among these alloys. Steels containing high concentrations of Cr, Mo, V, or Cu/Ni produced reduced wear than 52100 or plain carbon steels; D2 steel, containing 11.5 wt.% Cr, is the most wear resistant. The wear resistance correlates with the formation efficiency of carbon-containing films at the surfaces. This correlation holds for higher hardness steels and n-dodecane, a low viscosity lubricant. Molecular dynamics simulation on Cr2O3 demonstrated catalytic ability to form carbon-containing oligomeric films from hydrocarbons. Cr-containing alloys and coatings derive their wear resistance in part from in-situ formation of wear-protective tribofilms at contacting asperities.

2:30 pm – 3:00 pm

3812205: Holistic Measurement of the Friction Behavior of Wet Disk Clutches

Patrick Strobl, Georg Johann Meingaßner, Katharina Voelkel, Hermann Pflaum, Karsten Stahl, Technical University of Munich, Garching near Munich, Germany

Safe and efficient torque transmission in wet disk clutch systems requires high coefficients of friction. To achieve good controllability and high comfort, a positive slope of the coefficient of friction over sliding velocity is ensured by a reasonable formulation of the lubricant and choice of friction pairing. This results in low transmittable torque at very low sliding speeds. Thus, the occurrence of undesirable micro slip in dynamic operation modes must be considered for the design of safety-relevant clutch systems. This work presents a methodology for the holistic measurement of the friction behavior of wet disk clutches. It is suitable for numerous applications and supports a sound understanding of frictional properties in the range of sliding velocities occurring in brake shifts, through slip operation down to static torque transmission. Experimental determination of the holistic friction behavior is key to the development of optimized design guidelines for clutch systems.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3832307: SLiPP+ Fiber Fabric: Flexible Ultra-Low Friction and Wear Material by Mimicking Articular Cartilage

Hong Liu, Lanzhou Jiaotong University, Lanzhou, China

Articular cartilage is a thin layer of specialized connective tissue to provide a smooth, lubricated surface for low friction and facilitates the transmission of loads to the underlying subchondral bone. It shows a porous structure with chondrocytes and organized collagen fibrils. With an eye to heeding the lessons of nature, SLiPP (Self-lubrication Oil Impregnated porous polymer) material is combined with fiber fabric (Glass, Carbon) to produce a porous fibrous composite. Different polymers, such as Polyphenylene sulfide (PPS) and Phenolic resin, are successfully employed to fabric SLiPP materials to significantly decrease its cost. Moreover, fiber fabric such as Glass and Carbon is used to produce the SLiPP+ Glass/Carbon material. These SLiPP+ materials show outstanding tribological and mechanical properties while they also demonstrate the flexibility of fiber material, which can be widely used as the low friction material.

4:00 pm – 4:30 pm

3834379: Tribological Performance Evaluation and Enhancement of Bio-Lubricants by using Nano Additives and Ionic Liquids

Muhammad Bhutta, National University of Sciences & Technology (NUST), Islamabad, Capital, Pakistan

The environmental concerns associated with artificially formulated engine oils have forced a shift towards alternative lubricants. Base oil is produced by means of refining crude oil. In this research work 3 Bio-Lubricants, namely, Waste Cooking Oil, Cotton Saeed Oil and Ratanjot Oil have been prepared through Transesterification and their performance have been evaluated against polyalphaolefin (PAO) using ASTM 4172 Four Ball Testing. PAOs are extensively used in automotive fluids as well as hydraulic, gear and bearing oils, working in extremely cold climates or hot applications. Bio-Lubricants performance has been enhanced by using a combination Ionic Liquid and Nano-Additives. Results show a decrease in coefficient of friction by increasing load in in case of using Bio-Lubricants. Ratanjot Oil has shown comparative good performance when compared to PAO.

4:30 pm – 5:00 pm

3811472: Effect of Composition on Friction in Pine Loblloly Biomass Material

Maria Cinta Lorenzo Martin, Oyelayo Ajayi, George Fenske, Argonne National Laboratory, Lemont, IL; Jordan Klinger, Yidong Xia, Idaho National Laboratory, Idaho Falls, ID; Troy Semelsberger, Ricardo Navar, Los Alamos National Laboratory, Santa Fe, NM

The reliable and controlled flow of solid particulate biomass materials from bins, hoppers, etc. is essential for successful operation in every biorefinery. Friction is one of the critical material properties governing the flow of biomass materials and an important input into material handling equipment design. The current approach by industry to assess friction is different variants of shear testing. A bench top tribometer was adapted to measure friction of biomass materials by attaching copious amount of biomass materials unto sliding surfaces. The pressure within

the biomass during friction measurement was mapped using a pressure sensitive film technique. In this paper, the effect of the composition of pine loblolly particles in terms of anatomical fraction of bark, needle, stem and whole on friction behavior was evaluated by the new test method.

5:00 pm – 5:30 pm

Materials Tribology Business Meeting

Session 6E | 102C

Tribochemistry III

Session Chair: Nikolay Garabedian, Karlsruhe Institute of Technology, Karlsruhe, Germany

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3807754: Encapsulation of Halogen-Free Boron-Based Ionic Liquids within Polymer Microshells

Filippo Mangolini, Jieming Yan, Kenechukwu Moneke, The University of Texas at Austin, Austin, TX

Even though ionic liquids (ILs) are attractive for lubrication purposes owing to their unique properties (e.g., high thermal stability) and good tribological properties, their limited solubility in hydrocarbon fluids has hindered their employment in oil formulations. Here, we develop two methodologies, based on mini-emulsion polymerization and solvent evaporation, for encapsulating halogen-free, boron-based ILs (hf-BILs) within polymer shells with the aim of introducing these ILs in base oils in a concentration that exceeds their solubility limit. Macroscale tribological tests performed using synthetic oil containing encapsulated hf-BILs together with ex situ X-ray photoelectron spectroscopy measurements indicate that the mechanically-induced rupture of the polymer shells at sliding interfaces results in the release of the encapsulated ILs, whose surface adsorption reduces friction and wear. The new methodology paves the way towards the implementation of ILs in lubricant formulations.

2:00 pm – 2:30 pm

3834000: Differences in ZDDP and Ionic Liquid-Based Tribofilms

Florian Pape, Gerhard Poll, Leibniz University Hanover, Garbsen, Lower Saxony, Germany

To protect bearings against wear, additives in lubricants play an important role. ZDDP plays a very important role as an additive that forms a protective phosphate glass layer under load. A recent development is the use of phosphonium-based ionic liquids, which can also form phosphate-containing layers. In order to compare the layers formed, the formation of phosphate-containing layers under tribological contact was studied on samples of 100Cr6 rolling bearing steel in a rotating Anton Paar MCR with tribometer setup. In this test, the temperature was varied from 20°C to over 100°C. Finally, tests were also carried out on the FE8 test rig and the frictional torques and the layers formed were examined to draw conclusions about suitability.

2:30 pm – 3:00 pm

3833990: Mechanochemical Synergy Between Metal Oxide Nanocrystals and Surface-Active Molecules at Lubricated Contacts: An In situ Atomic Force Microscopy Study

Pranjal Nautiyal, Andrew Jackson, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Robert Wiacek, Pixelligent Technologies LLC, Baltimore, MD

Metal oxide nanocrystals are promising lubricant additives for harsh environments because of their ability to form protective tribofilms under elevated stresses at sliding contacts. We examine the tribochemical interactions between nanocrystals and reactive sulfur/phosphorus-containing anti-wear additives used in lubricants. We used atomic force microscopy to interrogate the nanoscale growth kinetics of tribofilms in situ for oils formulated with mixtures of ZrO_2 nanocrystals and three distinct classes of S/P additives: zinc dialkyldithiophosphate, phosphoric acid ester, and phosphate ester. For all three, a combination of nanocrystals and molecular additives gave faster tribofilm growth rates compared to the individual constituents. We hypothesize this synergy stems from simultaneous activation of stress-assisted sintering of nanocrystals and the mechanochemical reaction of surface-active S/P molecules. Depth-resolved chemical characterization elucidates tribofilm growth mechanisms.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3833100: 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.

4:00 pm – 4:30 pm

3811471: Understanding the Effect of Forces on Tribochemical Reaction Rates

Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

The effect of applied stress on the rates of tribochemical reactions is described using the Bell model, where the rate varies as exp(V‡/kBT), where V‡ is the activation volume. Strategies for measuring reaction pathways are illustrated using the gas-phase lubrication of copper by dimethyl disulfide (DMDS) where the rate of reaction of on a Cu(100) single crystal substrate is measured by exerting the force using an atomic force microscopy tip. The stress-dependent rates of these model systems are accurately measured using an atomic force microscopy tip and this enables models to be developed that can accurately reproduce the experimental data and the strategies for accomplishing this will be discussed in detail.

6E

4:30 pm – 5:00 pm

3833820: How are Chemical Reactions Activated in Tribological Interfaces?

Seong Kim, The Pennsylvania State University, University Park, PA; Ashlie Martini, University of California, Merced, Merced, CA

In recent studies of tribochemistry, a "mechanically-assisted thermal-activation" model is often used for mechanistic understanding. Conceptually, this model assumes the existence of a thermally-activated process with high activation energy and that the net effect of mechanical energy delivered by interfacial shear action is to lower this thermal activation energy. From the semi-log plot of tribochemical reaction rate or yield versus applied load or shear stress, the so-called "activation volume" can be determined. The magnitude of this activation volume can be quantified readily in both experimental and computational studies [Tribology Letters (2021) 69:150]. However, the physical meaning of its magnitude is still debatable. In this talk, we'll address the question if the activation energy of the hypothetical thermal reaction can really be determined. If yes, how such reaction pathways can be identified? If not, what does the activation volume really mean?

5:00 pm – 5:30 pm

3801783: In Situ Observation of the Effect of the Tribofilm Growth on Scuffing in Rolling Sliding Contact

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

General reductions in lubricant viscosities in many machine components mean that the role of lubricant additives in forming tribofilms has become increasingly important to provide adequate surface protection against scuffing. However, the relationship between scuffing and the formation and removal of tribofilms has not been systematically demonstrated. Here, a step-sliding speed scuffing test based on contra-rotation using MTM/ETM-SLIM has been employed to observe concurrently tribofilm thickness and scuffing. The initial sliding speed used was found to significantly affect scuffing performance since it determines the extent to which a tribofilm can form before critical sliding speed conditions are reached. In general, additives that formed thicker tribofilms, especially ZDDPs and triphenyl phosphate, gave effective protection against scuffing, though their protective tribofilms were progressively removed at higher sliding speeds, eventually resulting in scuffing.

Session 6F | 103A

Contact Mechanics II

Session Chair: Charchit Kumar, University of Glasgow, Glasgow, United Kingdom

Session Vice Chair: Melih Eriten, University of Wisconsin-Madison, Madison, WI

1:30 pm – 2:00 pm

3833768: Macro-Scale Characterization of the Contact Between Ski and Snow

Kalle Kalliorinne, Andreas Almqvist, Luleå University of Technology, Luleå, Sweden

In cross-country skiing, the time difference between a race winner and the person coming second is typically very small. Since much of the energy is spent on overcoming friction, a relatively small decrease can have a significant impact on the race results. One step towards understanding the frictional mechanisms between the ski and the snow is to characterize the tribological interface. The present method involves an ANN (Artificial neural network) and BEM (Boundary element method) based contact mechanics simulation method. Using this approach, the contact-mechanical response between the ski and the snow counter surface can be characterized at several scales. The results suggest that different skis will be optimal for minimizing the frictional forces under different snow conditions.

2:00 pm – 2:30 pm

3810729: Effects of Mechanical Stimulation on Reconstructed Skin at Different Levels of Maturity

Na Qiao, Ecole Centrale de Lyon, Ecully, France

Skin aging has always been an issue of great concern. Therefore, it is reasonable to explore the differential effects of mechanical stimulation on young and old skin samples. In this study, reconstructed skin tissues (young and old) were subjected to two types of mechanical stimulations: the indentation using a dynamic bioreactor and the shear wave generated by air using the device developed by our group. In indentation stimulus, all reconstructed tissues were compressed in the X and Y axis, with older skin being more compressed than younger skin. Collagen content in the young group increased, whereas in the old group decreased. However, after shear wave stimulation, young and old skins are extended in both directions. In addition, the degree of deformation of old skin is higher than that of young skin. The change trends of collagen content were the same as that of indentation stimulation.

2:30 pm – 3:00 pm

3812991: Impact of Plantar Pressure Variations on the Ski-Snow Contact During the Double Poling Cycle in Cross-Country Skiing

Gustav Hindér, Kalle Kalliorinne, Joakim Sandberg, Andreas Almqvist, Hans-Christer Holmberg, Roland Larsson, Luleå University of Technology, Luleå, Sweden

Cross-country ski related sports offer the most medals during the Winter Olympics Games. Double poling (DP) is one of the most frequently used sub-techniques and has been studied thoroughly, but never in connection with numerical simulations of the ski-snow contact. The present study aims to investigate the impact of the variations in plantar pressure distribution (PPD) during the DP cycle on the ski-snow contact. PPD was recorded during the DP cycle and used as input data to a ski-snow contact mechanics solver. An incorporated artificial neural network predicts the shape of the ski, and the solver outputs the contact area and the pressure distribution of the ski-snow interface for a given PPD, throughout the DP cycle. The results show that the variations of the PPD have a significant impact on the ski-snow contact. Improving the DP technique and selecting appropriate skis for the given snow conditions are therefore key factors affecting the performance during the DP cycle.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3810971: An Application of Hydrodynamic Lubrication Theory to Automotive Windscreen Wipers

Bradley Graham, James Knowles, Georgios Mavros, Loughborough University, Leicester, United Kingdom

The primary function of automotive windscreen wipers is to remove excess fluid and debris from automotive windscreens. Their effective operation is imperative for both the driver and ADAS systems to secure an unobstructed view of the road. Cleaning performance is strongly related to film thickness, but the latter also influences friction which in turn affects the wiper's vibration behavior. There is hence a need to be able to predict the thickness of the residual film to assess any impacts it may have on the ADAS systems and drivers view. This work combines a dynamic model of the wiper with hydrodynamic lubrication theory to

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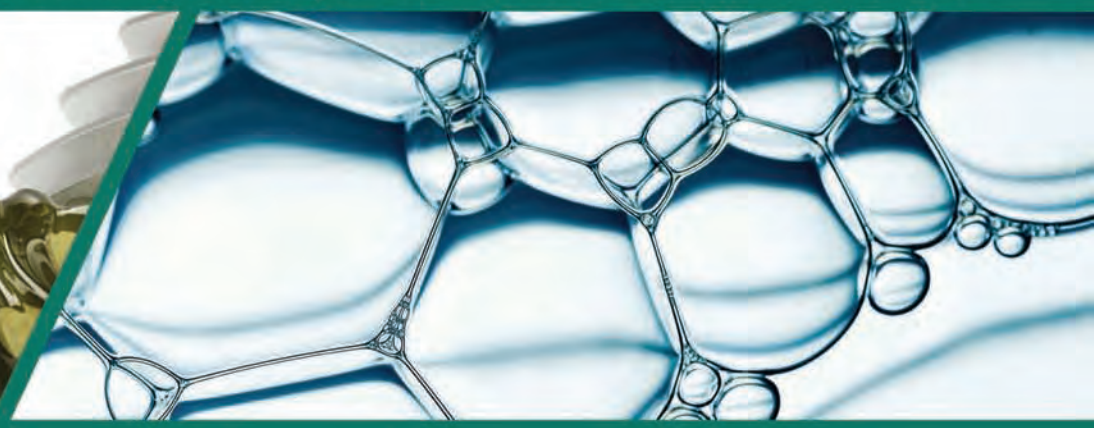

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calculate the residual fluid film thickness and transient friction coefficients. The results of this work agree well with known friction coefficient ranges of lubricated automotive wipers, with the friction coefficients ranging ≈0.1 0.6. Additionally, the estimated residual film thickness is found to be as thick as 10^(-5)m.

4:00 pm – 4:30 pm

3874029: The Effect of Friction Modifier on Piston Rings/Cylinder Liner Friction in Floating Liner Single-Cylinder Engine Tests

Abdullah Alenezi, Cayetano Conesa, Ardian Morina, University of Leeds, Leeds, United Kingdom

Measuring friction at piston rings/liner independently of other components enables a better understanding of the effect of chemical interactions between oil additives and the lubricated area. In this study, the AVL single-cylinder engine was used to perform fired and motored tests using fully formulated oils. Oils with various High-Temperature-High-Shear (HTHS) viscosities and molybdenum dithiocarbamate (MoDTC) additive concentrations are tested. This paper presents an analysis of friction force data to study the effect of MoDTC on friction during piston strokes, particularly at the top and bottom dead centres. The results show that MoDTC in a fired engine contributes to reducing friction at the BDC while at TDC, the MoDTC appears less effective. In motored tests, MoDTC reduces friction at both BDC and TDC, indicating the impact of combustion gases on low friction tribofilm formation at the TDC region. Friction results and chemical characterization of the tribofilm formed are discussed

4:30 pm – 5:00 pm

3812168: Relationship Between Hertzian Contact Pressure and Raman Band Shift: The Case of an Alumina-Glass Pair

Karl Delbé, Jean-Yves Paris, Malik Yahiaoui, École Nationale d'Ingénieurs de Tarbes, Tarbes Cedex, France

Optimising the performance of materials requires the characterisation of residual stresses at the design stage. Raman spectroscopy offers access to these residual stresses at the micrometre scale. In this case, the relationship between the Raman mode shift and the pressure must be known. We propose a new method that involves a Hertzian contact to obtain this relationship. Several Raman spectra are recorded into the contact between an alumina ball against a glass plane. Hertz's theory accurately describes the pressure profile as a function of position for elastic materials. We then deduce the correlation between the pressure profile and the spectral profile. We obtain results in good agreement with the literature for the Eg modes of alumina at 417 cm-1, at 2.07 cm-1/GPa. In the case of glass, we refine the measurement of the Q3 mode shift at 1096 cm-1 at a shift of 4.31 cm-1/GPa. This work opens up promising prospects for investigations in tribology.

5:00 pm – 5:30 pm

3834272: Flows Around a Contacting Asperity Modeled in the Micro and Nanometer Scales

Nicole Dorcy, Henry Soewardiman, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Asperity contacts commonly experience mixed lubrication conditions. It is important to understand how flow behaves when contacts reduce in size to the point that molecular forces become the dominant factor over bulk fluid dynamics. This work studies a fully flooded wedge in which a flat surface moves at a constant velocity relative to a fixed incline, focusing on the event in which the flow meets the corner of the wedge. Three scales are investigated by implementing three computational methods: computational fluid dynamics, elastohydrodynamic lubrication modeling via the Reynolds equation, and molecular dynamics simulations. The molecular dynamics approach aids mixed lubrication modeling by providing quantification of wall slip and details of the flows at asperity tips.

5:30 pm – 6:00 pm

Contact Mechanics Business Meeting

Session 6G | 103B

Tribotesting II

Session Chair: Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX

Session Vice Chair: Subin Jose, University of Nevada, Reno, Reno, NV

1:30 pm – 2:00 pm

3810635: Friction and Lubrication with Dry Powdered Soaps Used in Wire Drawing

Marie-Louise Schlichting, Marc Masen, Janet Wong, Amir Kadiric, Imperial College London, London, United Kingdom; Stijn De Pauw, Hendrik Van Hoecke, Marc Derdeyn, NV Bekaert SA, Ingelmunster, Belgium

Wire drawing is a process to produce steel wires that are used in a wide range of applications, from car tires to champagne corks. During wire drawing, the wire is pulled through a series of conical dies to reduce its cross-sectional area. This process uses vast amounts of energy and involves complex tribological conditions including high pressures, high speeds and dry powdered soaps as lubricant. High frictional forces at the wire-die interface are not only detrimental to the quality of the wire but also increase the energy consumption. Improving the wire-drawing process could entail significant economic and environmental benefits. Yet, the tribological conditions in wire drawing are barely studied. This work uses laboratory tests to study the frictional behavior of WC-steel contacts lubricated with dry powdered soaps, together with direct observations of the produced lubricating films. Presented results reveal new insights into the tribological interactions in the wire-die contact.

2:00 pm – 2:30 pm

3813312: Reducing Agglomeration of Gas-Phase Synthesized Graphene in Group IV PAO Base Oil to Enhance Antiwear Performance

Gordon Krauss, Huijie Li, Albert Dato, Harvey Mudd College, Claremont, CA; Matthew Siniawski, Loyola Marymount University, Los Angeles, CA

Gas-Phase Synthesized Graphene or GSG has been shown to reduce wear during pin-on-disc testing when used in small concentrations as an anti-wear additive in Group IV PAO base oil. However, the GSG tends to agglomerate over time negatively impacting the antiwear benefits. Prior studies examined demulsifier additives in conjunction with GSG with the exception that they would prevent the interference of small quantities of water which were believed to drive the agglomeration. This was not found to be effective. In this study, several dispersant additives were tested on PAO containing 0.1%wt. GSG, effectively reducing observed agglomeration of the GSG additive. This presentation describes image processing techniques applied to quantify agglomeration and POD wear test results for the oil with these additives. The data shows different effects of dispersant agents in terms of degree of agglomeration of GSG and on pin (ball) wear volume observed.

2:30 pm – 3:00 pm

3830800: Image Processing Test Development to Quantify Separation of Gas-Phase Synthesized Graphene from Base Oils and Predict Antiwear Effectiveness

Gordon Krauss, Huijie Li, Albert Dato, Harvey Mudd College, Claremont, CA; Matthew Siniawski, Loyola Marymount University, Los Angeles, CA

The effectiveness of Gas-Phase Synthesized Graphene or GSG as an antiwear additive decreases with time as it agglomerates and separates from the base oils. The factors controlling agglomeration are not fully understood, however an important aspect of studying this separation of GSG from the base oil and additives is quantification of the degree of agglomeration. This is complicated by the resulting dark color of the oil mixed with GSG and the size of the agglomerates. As a result, many traditional methods of quantification such as turbidity are ineffective. Micrographs of GSG containing oil with different concentrations of a dispersant additive are evaluated using a Python based image processing system. The size distribution of agglomerates and degree of separation is quantified and compared with pin-on-disc wear test data. This image processing tool may be effective in predicting the anti-wear behavior of GSG and possibly other nanomaterial containing lubricant additives.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3833989: Tribological Properties of the Cold Spray Deposited Cermet Coatings

Subin Jose, Pradeep Menezes, Ashish Kasar, University of Nevada, Reno, Reno, NV

The successful development of the multi-component cermet system is often difficult to achieve via conventional manufacturing routes. The cold spray deposition process can deposit ceramic materials with deformable metals to provide better deposition efficiency and superior coating characteristics. In this study, a mixture of Copper (Cu), Silver (Ag), Alumina (Al_2O_3), and Amorphous Boron (B) is successfully cold spray deposited on an Aluminum substrate (Al6061) to achieve cermet coatings. The microstructural and tribological studies of these coatings were tested at different temperatures. The influence of particle size on the deposition performance of cold spray coating is also carefully investigated.

4:00 pm – 4:30 pm

3824194: Soot Wear in Heavy-Duty Diesel Engine Oils

Thomas Kirkby, Tom Reddyhoff, Imperial College London, London, United Kingdom; Joshua Smith, Jacqueline Berryman, Infineum UK Ltd., Milton Hill, Abingdon, United Kingdom; Mark Fowell, Volvo Group Trucks Technology, Göteborg, Sweden

Soot levels in engine oils have increased due to longer service intervals and the drive to reduce emissions. This can lead to problematic wear of components especially in heavy-duty diesel engines. Lubricant and original equipment manufacturers (OEMs) use different tests and industry standards to quantify oil related durability of engines. However, our research using lab-based tribometer testing shows divergence in tribological performance between different types of test lubricant. Hence, we use test samples including field test engine oils, OEM dyno engine test oils, industry standard dyno test oils, and carbon black laden fresh oils. Certain oil samples seem to favor an oil degradation dominated wear mechanism while others favor a soot induced wear mechanism, even when apparent soot levels are equal. To demonstrate this and enhance understanding of soot interactions, we present High Frequency Reciprocating Rig friction and wear data correlated with measured lubricant properties.

4:30 pm – 5:00 pm

3831910: Accelerated Endurance Testing of Lubricants Using High-speed KRL Shear

Deepak Veeregowda, Fabio Alemanno, Ducom Instruments (EUROPE) B.V., Groningen, Netherlands; Debdutt Patro, Sravan Josyula, Ducom Instruments, Bangalore, India

The KRL shear stability test is one of the most severe tests to evaluate permanent viscosity loss of lubricants due to the high EHD stresses and long duration shearing. In this report, we explore the effect of speed on shear stability of lubricants. A standalone KRL shear stability with inline friction torque measurement module was used. Reference fluid, RL209, was sheared for 20 h and 100 h at 1475 rpm. In addition, RL209, was also sheared at 2450 rpm for 20 hours and 60 h. The coefficient of friction for all the tests were ~ 0.003 indicating an EHD lubrication regime for both standard and high-speed tests. The 60-hour accelerated test showed 30% higher permanent viscosity loss compared to a 100-hour standard test even though both accumulated ~ 8.8 million cycles indicating a shear rate dependence. Overall, acceleration of the KRL test to higher speeds reduced the test time by 40% while still providing reliable permanent viscosity loss data for a reference oil.

5:00 pm – 5:30 pm

3831927: Twin Disc Evaluation of Wheel Flange Lubricants and Top of Rail Friction Modifiers

Deepak Veeregowda, Fabio Alemanno, Ducom Instruments (EUROPE) B.V., Groningen, Netherlands; Debdutt Patro, Sravan Josyula, Ducom Instruments, Bangalore, India

Wheel flange (WF) lubricants are designed to reduce friction to low levels (CoF < 0.15) whereas top of rail (ToR) friction modifiers are designed for intermediate friction (0.15 < CoF < 0.35) so as not to affect safety factors like braking distance. In this study we evaluate both WF and ToR lubricants as per the BS EN 15427-2 standard. A twin disc tribometer with independent speed control and crowned on flat disc configuration was used. Fixed quantity of lubricant was applied to the discs before the test and loads selected to achieve a contact stress of ~ 1 GPa. Testing for both WF and ToR lubricants were conducted at fixed % slip and duration to obtain friction and retentivity characteristics. To obtain the creepage curves, tests were conducted with different speeds of the discs with % slip varying between 0.1 and 25%. The results for both WF and TOR lubricants would be compared and factors affecting precision presented.

5:30 pm – 6 pm

Tribotesting Business Meeting

Session 6H | 103C

Commercial Marketing Forum VI

Session Chair: TBD

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3909507: Tannas Noack S2® – Evaporation Loss and Expanded Capabilities – ASTM D5800 and CEC L-040

Brendan O'Shea, Tannas Company, Midland, MI

Evolving from Selby-Noack®, the original non-Wood's Metal Noack, the Noack S2® operates according to ASTM D5800 (Procedure D/B) and CEC L-040-93. Notable features include quick-connect fittings for rapid and stable test setup, touchscreen controller with user-friendly interface, and adjustable Orifice Tubes to easily calibrate 'tune' the instrument to lab environments. This instrument is not only used for daily volatility testing, but also for collection of volatiles for further investigation of phosphorus emission vapors. Recent interests for the Noack relate to new concept oils for both ICE and EV vehicles, with operation at lower temperatures (1500C) and expanded test times (4,8,12 hours). The Tannas Noack S2® is uniquely equipped to accommodate these varying parameters.

2:00 pm – 3:00 pm

3900667: Afton Chemical's Key Driver Seminar – Trends and Technological Challenges in Lubricating Greases for Rolling Bearings

Frank Berens, SKF Research & Technology Development, Saint-Cyr-sur-Loire, France; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands; Alyson Wilson, Afton Chemical Corporation, Richmond, VA

There are many challenges facing the bearing industry today. We will discuss the latest trends and technological developments impacting bearing and lubricant performance as well as sustainability developments, with examples of carbon footprint, energy consumption, and waste. We will share our insight on grease performance and the need for improved specifications that will allow for better grease selection methods and grease products. These specifications, in turn, will support the needs of more demanding applications, such as electric motors that trend towards increasing speeds and higher temperatures. At SKF Research, we are proposing a new specification for grease life and performance, referred to as the "Grease Life Factor (GLF) concept", providing a simple way to measure grease quality for ball bearings. These improved specifications and enhanced performance will involve collaboration between grease and bearing manufacturers, industry organizations, academia, and end users.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3908213: BASF Lubricant Solutions for the Future

Philip Ma, Donna Mosher, Arjun Goyal, Meredith Mosley, BASF, Florham Park, NJ

BASF's Fuel and Lubricant Solutions is a leader for sustainable high-performance drive train lubricants in selected transportation markets. With our leading progressive technologies for EMGARD® transmission and gear lubricants, we establish industry standards for high performance and sustainable lubricants through joint customer developments providing maximum value. This session will highlight those advancements in our BASF portfolio while highlighting areas of e-mobility and preparing for a sustainable future.

4:00 pm – 4:30 pm

3833772: Evonik Corporation: Innovative E-Mobility Solutions from Evonik

Adam Rice, Evonik Corporation, Richmond, VA

Evonik Interface and Performance is one of the leading partners in specialty additives for critical performance enhancing chemistries, such as corrosion inhibitors, antifoam/defoamers, friction modifiers, wetting agents and lubricity enhancers. Evonik is working to provide innovative solutions for rising technologies in mobility, electronics and energy. E-Mobility is changing the landscape of fluids and the related additives in order to meet demanding performance requirements. E-fluids for electric motors require additives that provide efficiency enhancing effects that serve these special requirements, for example in thermal management and lubrification. Evonik Interface and Performance offers a broad range of solutions for these applications focusing on Metal Corrosion, Foam Prevention, Thermal Conductivity, Electrical Conductivity, Lubricity, and Material Compatibility data while providing strong customer focused development and service for these demanding applications.

4:30 pm – 5:00 pm

3908131: Sasol Chemicals – SOFOL® Guerbet Alcohols and Their Derivatives

Meredith Perkins, Sasol, Houston, TX

As the metalworking and lubricant industry continues to strive for more effective formulas, the need for high performance additives has increased. The SASOL portfolio of high purity Guerbet alcohols (ISOFOL) can help you meet your target lubricant properties. Readily biodegradable, ranging from C12- C32 with even carbon chain lengths, ISOFOL can enhance solubility and solvency, oxidative stability, and lubricity. Additionally, ISOFOL alcohol derivatives such as esters and acids maintain many of the beneficial properties of the parent alcohol. This presentation will introduce the ISOFOL portfolio and provide many starting points for innovative lubricant products.

5:00 pm – 5:30 pm

3909483: Nouryon – Fatty Amine Chemistries and Polymer Technologies for the Lubricant Industry

Alvaro Jose Ortiz, John Dixon, Nouryon, Houston, TX

In today's context, lubricant companies are facing a dual challenge. Developing products with better performance and products that are more environmentally friendly. That requires a different set of capabilities. With a history of nearly +400 years as a global specialty chemicals leader, Nouryon will present its extensive natural derived amines and phosphate product families as well as its synthesis capabilities offering our customers a broad spectrum of components design possibilities enabling access to a large population of products and platforms solutions.

5:30 pm – 6:00 pm

3914393: Cargill: Dielectric Cooling Fluids and Low Traction Lubricants for Improved Electric Vehicle Performance

Scott Davis, Cargill, Wayzata, MN

Batteries are the single most expensive component in an EV and OEMs are seeking ways to improve efficiency. Greater efficiency means better range for the same battery size, or even a smaller battery pack for the same range. Consumers want improved usability with faster charging speeds and greater range. Here we will discuss how lubricants and dielectric cooling fluids can enable better performance in EVs by looking at how Cargill esters positively impact, traction, wear and thermal efficiency in both transmission and immersion cooling applications.

2023 STLE Annual Meeting

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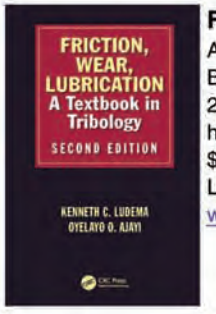

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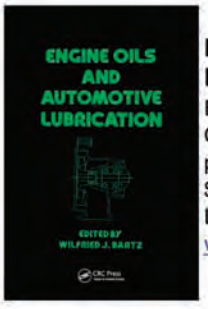

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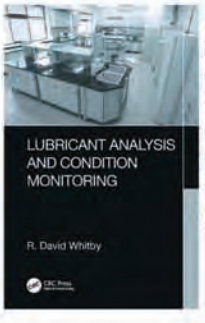

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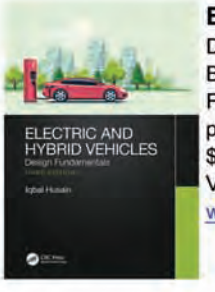

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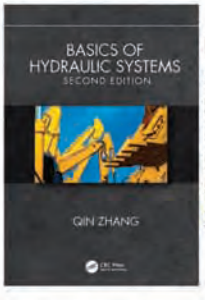

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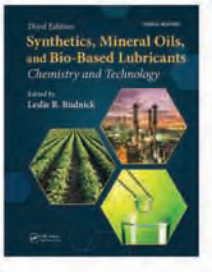

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Session 6I | 104A

Electric Vehicles VI

Session Chair: Dinesh Bansal, Chevron Oronite, LLC, Richmond, CA

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3804553: The Effect of Esters on the Tribological Performance of Electric Vehicle (EV) Transmission Lubricants

Johann Watson, Ardian Morina, Farnaz Motamen Salehi, Shahriar Kosarieh, University of Leeds, Leeds, West Yorkshire, United Kingdom; Gareth Moody, David Gillespie, Cargill, Snaith, East Yorkshire, United Kingdom

With the increased adoption of EVs and the new challenges they present, it is important to develop dedicated high performance EV lubricants. This study aims to experimentally evaluate the effectiveness of two esters as additives on the tribological performance of a fully formulated lubricant in conditions relevant to EVs. The effect of viscosity and polarity on traction has been studied using the MTM programmed for timed, Stribeck, and traction steps in the mixed and EHL regimes, simulating starting and running conditions in an EV transmission system. Wear has been analyzed with optical profilometry and imaging. Tribofilms chemical structure has been analyzed with the complimentary spectroscopy techniques Raman/SIMS/XPS. The results show improved stability and traction, with decreased wear when using esters. The tribological performance in relation to lubricant chemistry, testing conditions, and tribofilm structure will be discussed to explain the performance of esters in EV lubricants.

2:00 pm – 2:30 pm

3832111: Shelf-Stable hBN-Based Additive as Sulfur-Free Antiwear and Efficiency Booster for Low Viscosity E-driveline Fluid Applications

Peter Moore, Stephan Wieber, Dmitriy Shakhvorostov, Andreas Hees, Evonik Oil Additives, Horsham, PA

Solid lubricant materials have been documented in literature to have extraordinary tribological properties including very low friction in both boundary and mixed regime, anti-wear properties and pitting prevention. Additionally, solid lubricants such as hBN don't contain sulfur or phosphorous and aren't electrically conductive. Therefore, they fulfill crucial prerequisites for additives for use in EV applications with direct contact to copper and electrical componentry. A shelf-stable additive based on hBN has been developed as an anti-wear and efficiency booster in the low-speed high-torque regime that enables the formulation of sulfur-free and low viscosity e-drive formulations without compromise on copper corrosion and electrical conductivity. In this presentation performance data of the shelf-stable hBN-based additive in base oil and in formulated e-drive fluids will be presented compared to state-of-the art chemistry.

2:30 pm – 3:00 pm

3812753: Promising Aspects of Nanolubricants Use for EVs – A Critical Review

Waleed Ahmed Abdalglil Mustafa, Fabrice Dassenoy, LTDS/ECL, Ecully, France

Throughout the years, there has been steady progress in improving the performance of lubricants dedicated toward internal combustion engine (ICEs) vehicles. These improvements depend on utilizing functional additives that rely on tribo-chemical actions under the tribo-contact. However, new challenges are imposed on these conventional lubricants due to the rapid introduction of electric vehicles (EVs) to the market. Lubricants for EVs require standardized breakage voltage and conductivity properties in correlation to optimum tribological performance under high rpm, thermal management benchmarks, and corrosion resistance. Nanolubricants with nanoparticle additives can be more advantageous in tackling these obstacles when compared to the previous additives. This study critically reviews the latest studies on nanolubricants and how they meet EVs' operative needs. Findings from this work can be used as guidelines for applying nanolubricants in EVs and highlight research gaps in the theme.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3833573: The Effect of Friction Modifiers Under Ultra-Low Viscosity Engine Oils

Kenji Yamamoto, Kouichi Takano, Shinji Iino, ADEKA Corporation, Tokyo, Japan

Electrified ICE equipped vehicles are important to reduce the CO2 emission for coming decades. Since HEV are operated under low temperature more frequently, the effect of ultra-low viscosity engine oil for FEI would be more significant. Ultra-low viscosity engine oils such as 0W-8 are introduced to Asian market in 2019 with JASO GLV-1, and these viscosity grades are under discussion for implementing ILSAC specification as well. The effect of friction modifiers with those ultra-low viscosity engine oils are significantly higher than with conventional viscosity grades because of their more frequent contact of surfaces. In this study, friction reduction performances of several friction modifiers with 0W-8 and 0W-20 formulated with GF-6 additive technology are evaluated under bench tests and motored engine friction tests. As a result of study, MoDTC exhibited significant friction reduction performance compared to other FM technologies especially with 0W-8 viscosity grade.

4:00 pm – 4:30 pm

3818318: The Response of Phosphonium Ionic Liquids (ILs) in Lubricating Greases with Respect to Various Tribological Contacts

Eamonn Conrad, William Stibbs, Solvay, Niagara Falls, Ontario, Canada; Mehdi Fathi-Najafi, Jinxia Li, NYNAS, Nynashamn, Sweden; Derek Voice, Jean-Noel Tourvielle, Solvay, Niagara Falls, Ontario, Canada

There are many challenges facing today's electric vehicle (EV) manufacturers. When selecting EV lubricants and greases, companies often rely on iterative improvements to formulations designed for internal combustion engines. These lubrication systems present challenges and fail to substantially improve system efficiency. Vehicles running with conventional or modified lubricants in EV lose as much as 30% of efficiency due to losses directly associated with lubrication. This presentation demonstrates the responses of phosphonium ionic liquids as metal free/ashless additives to deliver AW/EP properties and thermal/electrical conductivity improvements, beneficial to this application with specific focus on lubricating greases.

4:30 pm – 5:00 pm

3815330: Influence of Additive/Ionic Liquid Concentration on the Electrical and Tribological Properties of an ATF

Alejandro García Tuero, Noelia Rivera Rellán, Alfonso Fernández González, José Luis Viesca Rodríguez, Antolín Estaeban Hernández Battez, University of Oviedo, Gijón, Asturias, Spain

Some electric vehicles have the electric motor inside the transmission housing, and in contact with the automatic transmission fluid (ATF). This ATF must fulfil special requirements, such as electrical compatibility, to avoid current leakage or possible discharges due a buildup of charges. This work studies how the concentration of additives, including a phosphonium-based ionic liquid (IL), can impact on the electrical (conductivity, resistivity, permittivity, dielectric dissipation factor, and breakdown voltage) and tribological properties of an ATF. The results show that friction and wear reduction occur by adding the IL, and the electrical conductivity was increased, although it remained being dissipative. The dielectric properties dropped to around 1 kV in the IL-containing samples, so further measurements need to be made. The increase in the additive concentration improved tribological properties and maintained the electrical compatibility of the samples.

5:00 pm – 5:30 pm

3810591: Investigation on Gear and Bearing Protection with Lower Viscosity Lubricants for Electric Vehicles

Hiroyuki Tatsumi, Kazushige Matsubara, Yasuhito Nakahara, Daisuke Takekawa, Keiichi Narita, Idemitsu Kosan Co., Ltd., Ichihara-shi, Chiba, Japan

From the viewpoint of reducing environmental impact, electric vehicles are becoming increasingly popular. Lubricants are also required to have suitable performances for them, and we have previously reported that lower viscosity lubricants are effective for motor cooling performance. However, reducing the viscosity causes a decrease in the protection performance of mechanical components, so it is necessary to maintain and improve them with lubricant additives. In this study, we investigated in detail the protection performance of gears and bearings in lower viscosity lubricant oil for electric vehicles. As a result, it was found that optimizing the phosphorus-based extreme pressure agent can protect the friction surfaces and improve both anti-scuffing and anti-fatigue performances. In addition, the study of the effect of friction properties showed that lubricants with reduced friction coefficients tended to improve the gear fatigue life.

5:30 pm – 6:00 pm

3834101: Combining Durability and Efficiency for Electric Vehicle Transmission Fluids

Thorsten David, Castrol, Hamburg, Germany

Range anxiety remains one of the fundamental issues when convincing customers to switch from ICE-powered cars to electric vehicles and thus the efficiency of the drivetrain remains crucial. As efficiency benefits are mainly achieved through lower viscosity fluids it is important to put an emphasis on the durability of such EV Transmission Fluids. In this presentation it shall be demonstrated how EV Transmission Fluids can further improve the drivetrain efficiency whilst providing a high level of hardware protection. This includes durability testing on rigs as well as on transmission level.

6:00 pm – 6:30 pm

Electric Vehicles/Engine & Drivetrain Business Meeting

Session 6K | 201A

Tribology of Biomaterials I

Session Chair: Kylie Van Meter, Florida State University, Tallahassee, FL

Session Vice Chair: Allison Chau, University of California, Santa Barbara, Santa Barbara, CA

1:30 pm – 2:00 pm

3832182: The Role of Gradient Layer on Depth-Dependent Adhesion in Hydrogel Using AFM Nano-indentation

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

The gradient softer outer layer, found in many biological systems or synthetic crosslinked hydrogels, plays a crucial role in their interaction with the countersurfaces. Our previous research showed that a gradient layer controls the contact mechanics at the submicron scale (the scale close to the layer thickness). We hypothesize that the water redistribution in loose chains will lead to adhesion behaviors that may also play a role in the biological function. In this study, we have measured the indentation adhesion of polyacrylamide (pAam) hydrogel at different indentation depths (from 50nm to 1200nm) using a colloidal probe Atomic Force Microscopy (AFM). Our results showed that at shallow indentation depth, the adhesion is much stronger due to the easier chain pull out, driven by increased fluid-transport near the contact, from the softer gradient layer when the probe retracts. These results allow a more accurate understanding of depth-dependent adhesion in a gradient layer surface.

2:00 pm – 2:30 pm

3832706: Dynamic Viscoelasticity Measurement of Hydrated Polymer Brush Film in Narrowing Shear Gap

Fengchang Lin, Shintaro Itoh, Kenji Fukuzawa, Naoki Azuma, Hedong Zhang, Nagoya University, Nagoya, Aichi, Japan

2-Methacryloyloxyethyl phosphorylcholine (MPC) polymer brush is known as a promising coating material for artificial joints due to its excellent lubricity. Friction coefficient of the MPC polymer brush film showed dependence on the shear gap. This is presumably because polymer brushes' mechanical properties (viscoelasticity) changed in different shear gap. However, it is difficult to measure viscoelasticity's shear gap dependence due to the very small film thickness. In previous studies, we have developed a fiber wobbling method (FWM), which can measure the shear gap dependence of dynamic shear viscoelasticity of nanometer-thick liquid films. In this study, we improved FWM and measured the dynamic shear viscoelasticity of hydrated MPC polymer brush film in a narrowing shear gap. The shear gap dependent dynamic shear viscoelasticity is resulted from a dehydrating process of the MPC polymer brush film during compression.

2:30 pm – 3:00 pm

3832949: Relationship Between Friction Coefficient and Permeability of Physically and Chemically Crosslinked Hydrogels

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

Hydrogel preserves their shape because of the crosslinking of polymer chains. The transport parameters, like permeability, are significantly influenced by the hydrogel concentration or pressure gradients that move the fluid through the polymer mesh. A flow pressure-controlled permeameter was developed to determine the permeability of hydrogels like pAAm, and PVA at various polymer concentrations and compare the

permeability variation due to chemical and physical crosslinking. The sliding test would help understand the relationship between variation in permeability and friction coefficient. The aim is to find the relation between chemically and physically crosslinked hydrogel surface properties difference for varying concentrations and an attempt to link it to structural properties like permeability. In addition, these hydrogels were layered at these varying concentrations with a thickness of 0.2mm layers to see whether the contact mechanics change by structured layers affect friction.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3810826: Sliding Friction Through Dislocation Glide in Shape Complementary Soft Interfaces

Jasreen Kaur, Lehigh University, Bethlehem, PA

Friction behaves differently at different scales; we study friction at the microscale using shape complementary polymeric structures. These bio-inspired structures are used to enhance friction selectivity which has applications ranging from rubber processing in tire manufacturing to object handling in soft robotics. PDMS is patterned with fibrillar microstructures to create the samples. A custom-built tribometer is used to measure friction between the two complementary samples. The two samples when brought in contact with each other spontaneously produce an array of dislocations depending on the misorientation and lattice spacing between the two samples. These dislocations are micron-scale replicas of dislocations produced on atomic scale. The two samples when subjected to relative sliding motion do so by the interfacial glide of dislocation structures. We also conduct finite element analyses to study how individual fibrils interact with each other.

4:00 pm – 4:30 pm

3834053: Study of Biological Interfaces – From Cartilages to Personal Care Products

Kartik Pondicherry, Anton Paar GmbH, Graz, Austria; Mayank Warshney, Anton Paar India, Gurugram, India; Paul Staudinger, Julius Heinrich, Anton Paar GmbH, Graz, Austria

In the recent years, there has been an increased interest in the study of biotribological interfaces as well as personal care products ranging from lipsticks to deodorants to condoms and personal lubricants. As each case is more or less unique, the test setup as well as the test methodology need to be adapted to cater to the real-life application. In the current work, the authors present case studies from various applications wherein focus is laid on the test and method development, including the challenges one faces in the process. In most of the studies, it was found that the choice of material used as a surrogate for the real-life biological surface place a very critical role. The authors also present a specific case from food tribology wherein a model was created to correlate tribological data with that obtained from a human sensory panel.

4:30 pm – 5:00 pm

3834204: Characterization of Mechanical Properties of Solvent-Cast 3D-Printed Peptide-Polymer Scaffolds for Osteochondral Tissue Regeneration

Santiago Lazarte, Tomas Babuska, Catherine Fidd, Brandon Krick, Florida State University, Tallahassee, FL; Tyler French, Diana Hammerstone, John Tolbert, Andrew Kitson, Lesley Chow, Lehigh University, Bethlehem, PA

Interactions between cells and biomaterials are essential to regenerating functional tissue. Cells are affected by the chemical, mechanical and other biological cues from their microenvironment. These cues can be functionally embedded in 3d-printed scaffolds for directing mesenchymal stromal cell (MSC) differentiation to spatially direct tissue regeneration. In many tissue regeneration applications, including the osteo-chondral (bone-cartilage) system, the mechanical properties of the scaffold must be tuned to perform a physiological function (i.e., support load) while the new tissue is generated. This work explores how differences in the architectures of solvent-cast 3D printed peptide-polymer scaffolds as well as polymer conjugate concentration will affect their mechanical properties. In this work, we explore different metrics for characterizing the mechanical properties of the scaffolds, mainly through microindentation.

5:00 pm – 5:30 pm

3834223: In Situ Measurements of Syringe-Stoppers Contact Interfaces in Deep Cold Storage for Shipment and Storage of Biologics

Adam DeLong, Kylie Van Meter, Catherine Fidd, Brandon Krick, Florida State University, Tallahassee, FL; Nestor Rodriguez, Guilllaume Lehee, Grace Lin, Ludovic Gil, BD Medical-Pharmaceutical Systems, Pont de Claix, France

New drug technologies, like mRNA-based COVID vaccines, require cold storage, ranging from -40°C to < -80°C to ensure stability. During cold storage, prefilled syringes – comprised of a glass or polymer barrels, rubber stopper, and a lubricant – undergo thermal, mechanical, and physical changes that can affect the integrity of the seal. The focus of this study is to understand the effects of the freeze-thaw cycle experienced by these prefilled syringes. A custom cryostat has been created to thermally cycle prefilled syringes comprised of a glass and polymer syringes with a silicone oil lubricated butyl rubber stopper and filled with deionized water. An adaptive optics system was employed to measure the contact and position of the syringe barrel-lubricant-stopper interface in situ, as a function of temperature. The results show how cyclical freezing and thawing affect the complex behavior of the prefilled syringe system.

5:30 pm – 6:00 pm

Biotribology Business Meeting

Session 6L | 201B

Surface Engineering II

Session Chair: Auezhan Amanov, Sun Moon University, Asan, Republic of Korea

Session Vice Chair: Kora Farokhzadeh, DSM Engineering Materials, San Jose, CA

1:30 pm – 2:00 pm

3832278: Tribological and Tribo-Corrosion Mechanisms of Al7075-T6 alloy by Ultrasonic Nanocrystal Surface Modification

Auezhan Amanov, Young-Sik Pyun, Sun Moon University, Asan, Republic of Korea; Domenico Furfari, Airbus Operations GmbH, Hamburg, Germany

It has been a great challenge to employ effective, simple, and economical surface engineering technologies to control the tribological properties of materials. The objective of this study is to investigate the effect of ultrasonic nanocrystal surface modification (UNSM) technology on tribological and also tribo-corrosion properties of Al 7075-T6 alloy. Microstructural evolution together with surface properties (roughness, hardness, residual stress, XRD pattern, EBSD) before and after UNSM treatment were discussed. Both tribological and tribo-corrosion properties of the UNSM-treated Al 7075-T6 alloy were better than the untreated one. Wear and corrosion mechanisms were discussed to shed

light on the effectiveness of UNSM technology. It is expected that the aerospace industry may be benefited from the features of UNSM technology, such as an increase in strength, residual stress, wear resistance, and corrosion resistance of Al 7075-T6 alloy.

2:00 pm – 2:30 pm

3809868: A Multiscale Modeling System for Surface Texturing a Radial Pump Plunger to Improve Tribological Performance

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

The plunger-bore interface of a fuel pump is critical for the efficient delivery of high-pressure fuel. This interface has a clearance of at most a few microns and is subjected to misaligned plunger motion, prompting scuffing under marginal lubrication conditions. Proper textures on these components may help enhance lubrication, decrease friction, and control lubricant leakage, thus increasing the pump's lifespan. Presented here is a multiscale modeling system of the pump, which couples system-scale simulations and an interface analysis, aiming to develop a robust and efficient plunger-bore interface. The system models identify structural and fluid conditions of the full fuel pump, while the interface model explores critical rubbing conditions and the effects of surface texturing on the interface performance. A surface design scheme is proposed, promising textures are selected, and their performances are evaluated.

2:30 pm – 3:00 pm

3815718: Interaction Between Lubricants and Surface Texture Under EHL Conditions

Mohd Syafiq Abd Aziz, Tom Reddyhoff, Jie Zhang, Imperial College London, London, England, United Kingdom; Mohd Syafiq Abd Aziz, Universiti Teknikal Malaysia Melaka, Durian Tunggal, Malaysia

Applying surface texture to the surfaces of sliding components can be a powerful way to improve tribological performance, for instance reducing friction or wear. As a result, there has been considerable research effort expended on textured surface, often focusing on the effect of geometric texture parameters. However, there have been far fewer studies into the effect of lubricant composition on surface texture performance. To address this, we present recent research in which the friction reducing performance of surface textured components are compared to the of a non-texture reference for a range of commercial and model lubricant formulations. As well as showing how lubricants can be optimized for texture contact, results show how specific additives interact with texture features and thus shed light on the mechanisms that are occurring.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3814721: Adjustment of the Properties of Frictional Hysteresis Loops in Metallic Contacts by Surface Engineering

Mirco Jonkeren, Katharina Brinkmann, Matthias Wangenheim, Leibniz University of Hannover, Garbsen, Germany; Paolo Giudici, ML ENGRAVING srl, Onore, Italy; Anastasia Dianova, Marta Brizuela, TECNALIA, Basque Research and Technology Alliance (BRTA), Donostia-San Sebastián, Spain

Frictional contacts with cyclic relative motion exhibit frictional hysteresis loops if the frictional force is plotted against the relative displacement. The area within the hysteresis loop is a measure of the frictional energy dissipated per oscillation period. It is utilized as frictional damping in metallic contacts e.g., in turbine blade applications to handle critical vibration phenomena. In this work we investigate the possibility of modifying the shape of the hysteresis loop by laser surface texturing and coating of the metallic contact partners. The goal is to adjust static and dynamic coefficients of friction separately and to modify the velocity dependence of the dynamic coefficient of friction. The results of an experimental campaign with 20 different surface textures and coatings with respect to cyclic relative motion are presented, showing an increase of the frictional energy dissipation of up to 35%.

4:00 pm – 4:30 pm

3813005: Combining Concentrated Polymer Brushes and Laser Surface Texturing to Achieve Durable Superlubricity

Sorin-Cristian Vladescu, King's College London, London, United Kingdom; Chiharu Tadokoro, Takuo Nagamine, Saitama University, Saitama, Sakura, Japan; Mayu Miyazaki, Ken Nakano, Yokohama National University, Yokohama, Japan; Tom Reddyhoff, Imperial College London, London, United Kingdom; Shinya Sasaki, Tokyo University of Science, Tokyo, Japan; Yoshinobu Tsujii, Kyoto University, Kyoto, Japan

Concentrated polymer brushes (CPBs) have recently attracted significant scientific attention due to their ability to achieve superlubricity (i.e., coefficients of friction below 0.01), promising a new means of reducing energy losses in mechanical systems. However, their durability remains a limiting factor. To study CPB wear mechanisms, we grafted CPBs atop a novel picosecond-laser-etched matrix of micron-sized dimples. We employed a custom-built optical test apparatus to investigate the inter-dependencies between CPBs and laser-produced surface texture (LST), assessing for the first time the friction, film thickness, and wear behavior in situ and simultaneously. At low sliding speeds, combined CPB–LST reduces the friction coefficient to 0.0006, while increasing CPB durability by up to 34%. The imaging results shed light on mechanisms of lateral support offered by micro-features and failure propagation impacting CPB wear resistance.

4:30 pm – 5:00 pm

3812590: Increasing Tire Tread Ice Traction by Superhydrophobic Laser Texture

Matthias Wangenheim, Michael Hindemith, Leibniz University of Hannover, Hannover, Germany

The lack of traction on ice, partcularly on glaze ice is one of the main causes of dangerous driving situations and traffic accidents on winterly roads. While on dry, rough surfaces the most relevant rubber friction mechanisms hysteresis (deformation) friction and adhesion dominate the friction contact these mechanisms are impeded on ice close to the melting point. On the one hand these ice surfaces tend to be relatively smooth and on the other hand they are covered by a liquid water level of a few up to many molecule layers causing coefficients of friction lower than 0.1. In the course of this work, we textured a winter tire tread surface with a superhydrophobic pattern by picosecond laser ablation. Our hypothesis was that the liquid water layer would be repelled from the contact by the superhydrophobic rubber surface resulting in a quasi-dry rubber-ice contact. Experiments resulted in a coefficient of friction of up to 0.8 which is a very promising success of this approach.

5:00 pm – 5:30 pm

Surface Engineering Business Meeting

Session 6M | 202A

Grease II

Session Chair: Salil Bapat, Purdue University, West Lafayette, IN

Session Vice Chair: Lu Fang, University of Pennsylvania, Philadelphia, PA

1:30 pm – 2:00 pm

3814128: Shear Properties of Various Greases in Micrometer-Order Gap

Hanul Chun, Tomoko Hirayama, Naoki Yamashita, Kyoto University, Kyoto-shi, Nishikyo-ku, Kyoto-fu, Japan

Grease lubrication is widely applied to sliding parts under severe condition in bearings that support EV motor shafts and wind turbine shafts, for examples. Therefore, understanding the behavior of grease in micrometer-order gap is imperative to improve the lubrication performance more efficiently. However, the research on grease in micrometer-order gap are still few because a typical rheometer can only provide shear properties of samples in submillimeter-order gap. In this study, the shear properties of several kinds of greases with various thickener structures inside were measured by the original viscometer, which is able to measure the shear properties with maintaining a micrometer-order gap supported by an aerostatic bearing.

2:00 pm – 2:30 pm

3833718: Impact of Thermo-Mechanical Aging of Grease During Churning on Grease Properties and Life

Sathwik Chatra K R, SKF, Houten, Netherlands; Jude Osara, University of Twente, Enschede, Enschede, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

In grease-lubricated rolling bearings, grease ages during the churning phase due to high shear and temperature caused by macroscopic flow. In this study, we explore two different models to quantify the energy dissipated in the grease during churning by utilizing the temperature profile. One model estimates the imposed temperature-corrected energy density and the other estimates the heat transfer entropy density. Both models show good correlations with the measured degradation parameter yield stress and with measured grease life.

2:30 pm – 3:00 pm

3815401: Effects of Shear Aging on Oil-Separation Properties of Lubricating Greases

Femke Hogenberk, Jude Osara, Dirk Van Den Ende, University of Twente, Enschede, Overijssel, Netherlands; Piet Lugt, SKF, Houten, Utrecht, Netherlands

Controlled release of base oil from lubricating greases, referred to as bleeding, is fundamental to the lubrication of rolling bearings. Over time, the thickener structure of the grease will degrade, while the oil content is reduced due to the bleeding. Consequently, the bleed rate, i.e., the rate at which oil is released, may change. The effect of aging on bleed rate is studied for five types of greases. Grease samples are subjected to shear aging using a grease worker, equipped with a load cell to capture the imposed energy density. No significant change in bleed rate is observed for the studied range of imposed energy densities, even though softening of the grease after aging is observed. A permeability model is used to explain these observations. Moreover, a comparison with data from rolling bearing tests shows that higher imposed energy densities are required to obtain significant changes in bleed rate.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3823866: Bevel Gear Grease – A Sustainability Case Study

Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden

This paper summarizes two recent studies which together highlight both the importance and the complexity of including in-service performance when assessing the environmental footprint of a lubricant. The first study focuses on the development of a new grease for nutrunner bevel gears. Here we show that the durability and energy efficiency of both the gear and the grease can be significantly enhanced when modern grease formulation solutions are applied. The second study compares the grease formulations using two different LCA approaches that highlight the importance of a more holistic, cradle-to-grave approach, incorporating data from bench and field tests, versus a more limited cradle-to-gate approach. In essence, the core message of this paper is that the performance of lubricated machine elements can have a very significant impact on sustainability assessments and that a grease providing better performance can, even if it requires more resources to produce, be the superior solution.

4:00 pm – 4:30 pm

3830847: 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.

4:30 pm – 5:30 pm

Grease Business Meeting

Session 6N | 202B

Wear I

Session Chair: Khosro Shirvani, SUNY Farmingdale, Farimingdale, NY

Session Vice Chair: Mathieu Renouf, Universite De Montpelllier, Montpellier, France

1:30 pm – 2:00 pm

3803642: Adjusting for Running-In: Extension of the Archard Wear Equation

Michael Varenberg, John Crane, Inc., Morton Grove, IL

The Archard equation is widely employed to predict wear in engineering practice, but its use is usually restricted to the cases of sufficiently long wear duration, so the transient running-in behavior can be neglected with respect to the steady-state wear. To address this problem, here the steady state wear equation is extended into the running-in regime based

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on the bearing ratio curve representing the initial surface topography. This approach is verified using a unidirectional dry sliding of steel against PTFE and the extended equation is shown to be able to predict service life or to obtain wear coefficients regardless of the test duration if the initial surface topography is defined. It is also found that the bearing ratio curve can be efficiently approximated using the logistic function calibrated by four standard surface roughness parameters. This approximation proves to be more accurate than the widely used Gaussian normal distribution function.

2:00 pm – 2:30 pm

3803822: An Advanced Numerical Model for Wear

Jamal Choudhry, Andreas Almqvist, Roland Larsson, Luleå University of Technology, Luleå, Sweden

Wear is a complex phenomenon that may depend on several factors such as, surface roughness, material properties and operating conditions. Classical wear laws, such as Archard's wear law, rely on using a single wear coefficient to predict wear. This may raise issues since the wear coefficient may not be constant but depend on the many complexities that were just mentioned. For this reason, there is a need to develop a numerical wear model that accounts for all these complexities and accurately predict wear. In present work, an advanced numerical method is used to predict the wear of interacting asperities on the micro-scale contact region of the surfaces. The numerical model uses an advanced particle method to discretize the asperities and predict the large plastic deformations up to fracture. It is shown that this advanced model can be used to calibrate and obtain a more sophisticated wear coefficient in Archard's wear law, used in classical BEM calculations.

2:30 pm – 3:00 pm

3806376: Wear Behavior of Metallic Part Repaired by an Additive Manufacturing Process

Théo Zurcher, Eric Charkaluk, Laboratoire de Mécanique des Solides-Ecole Polytechnique, Palaiseau, France; Vincent Fridrici, Bruno Berthel, Laboratoire de Tribologie et Dynamique des Systèmes-Ecole Centrale de Lyon, Lyon, France; Benoit Dodin, Société Nationale des Chemins de fer Français, Saint-Denis, France

Additive manufacturing processes and more specifically the Laser Metal Deposition process belong to a new family of processes which are standing out in the past 20 years and offer the possibility to repair worn out metallic parts. This study investigates the wear behavior of metallic parts repaired by this innovative process. Samples were built by using different scanning strategies with different materials (Inconel718 and 316L SS). Regardless of the deposited material, the scanning strategy and the sliding direction do not impact tribological properties. However, tribological parameters (normal force, frequency, temperature …) have a great impact on the observed wear mechanisms. Wear tracks, counterbody faces, and wear debris were studied trough several characterization methods. Effects on friction and wear volume were also analyzed and discussed. The results were compared to results for conventionally manufactured materials: the competitiveness of this LMD process is highlighted.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3807117: Tribology Analysis of Additive Manufactured, Nickel-Based Super Alloys

Khosro Shirvani, SUNY Farmingdale, Farmingdale, NY

Nickel-based super alloys such as Inconel 718 (INC 718) can be manufactured through traditional and additive manufacturing (AM) methods. This study compares the tribological characteristics of traditionally manufactured INC 718 to additive manufactured INC 718. This is a significant study as INC 718 is an extremely hard material which results in a high rate of tool wear and expensive tooling parts. Developing an additive manufacturing method for INC 718 will eliminate the machining step, allowing the material to be built directly into the desired part and shape. Wear, weight loss and coefficient of friction were all measured with a pin-on-disc wear tester. By testing various loads, distance and speeds on the pin-on-disc tribometer, we were able to have a comprehensive understanding of mechanical and wear properties of INC 718 manufactured through two different methods leading to a better understanding of the benefits and limitations of the new methods of manufacturing.

4:00 pm – 4:30 pm

3810351: Effects of Temperature and Lubricant on Reciprocating Sliding Wear Behavior of HNBR/FKM

Zhangyu Qiao, China University of Petroleum, Beijing, China

As one of the crucial parts of downhole tools, the sealing rubber is vulnerable to wear and failure resulting from the harsh working condition. However, the tribological properties of rubber under this downhole sever condition have not been fully studied. Therefore, the tribotest of HNBR/FKM at 100 under different lubrication conditions and temperature was conducted. Wear volumes and worn surface morphology were analyzed in detail. The results show that under non-lubricated environment, the wear volume of HNBR shows a great increase at 1000C, while the wear volume of FKM presents a decrease trend. The Salamach stripes were found on the wear surface of HNBR, which is a typical feature of abrasive wear. The findings demonstrated the fluorine rubber has excellent wear resistance under downhole harsh environment.

4:30 pm – 5:00 pm

3812212: Computational Modelling of the Antiwear Effect of Zinc Dialkyldithiophosphate Tribofilms in Mixed Mode Lubricated Contact

Robert Anderluh, Hrvoje Jasak, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom

Zinc dialkyldithiophosphate (ZDDP) is still the most commonly used antiwear additive in the field of lubrication. Recent experimental discoveries have improved our understanding of the mechanisms through which ZDDP-induced tribofilms form and protect surfaces of components exposed to sliding contact. The aim of this study is to review the current understanding of those mechanisms and to incorporate that knowledge into a computational model capable of simulating rough surface elastohydrodynamic lubrication (EHL) contact mechanics problems. The model is developed in OpenFOAM, an open-source code library, most often used in the field of computational fluid dynamics, but capable of tackling many general continuum mechanics problems. Results of the novel model are finally compared to existing experimental measurements.

5:00 pm – 5:30 pm

Wear Business Meeting

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Overview

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Thursday, May 25

Registration
6:30 am – 12:00 pm – **Convention Center Foyer**

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

Education Courses* (8:00 am – 5:00 pm)

- Electric Vehicles – **104B**

Technical Sessions (8:00 am – 12:00 pm)

7A • Lubrication Fundamentals VII: Nanoparticles and Coatings – **101A**
7C • Seals I – **102A**
7E • Tribochemistry IV – **102C**
7F • Biotribology I – **103A**
7G • Tribotesting III – **103B**
7H • Commercial Marketing Forum VII – **103C**
7I • Electric Vehicles VII – **104A**
7J • Metalworking Fluids V – **201A**
7K • Surface Engineering III – **201B**
7L • Grease III – **202A**
7M • Wear II – **202B**

Refreshment Break
10:00 am – 10:30 am – **Foyer**

Lunch (on your own) – 12:00 pm – 1:30 pm

Technical Sessions (1:30 pm – 6:00 pm)

8C • Seals II – **102A**
8F • Biotribology II – **103A**
8G • Tribotesting IV – **103B**
8I • Electric Vehicles and Engine and Drivetrain VIII – **104A**
8L • Grease IV – **202A**
8M • Wear III – **202B**

Refreshment Break
3:00 pm – 3:30 pm – **Foyer**

TIME	SESSION 7A Lubrication Fundamentals VII Room 101A		SESSION 7C Seals I Room 102A
8:00 am – 8:30 am	Influence of Lubricant Additive Urea-ZrP on Viscosity, K. Arole, p. 150		Modeling and Simulation of the Dynamic Sealing and Lubrication Mechanism of Rotary Shaft Seals, J. Grün, p. 151
8:30 am – 9:00 am	Macro Topography Effect on Friction in Presence of Surface Textures in Conformal Contacts, G. Vaitkunaite, p. 150		A Secondary Self-Opening Start-Up Clearance Seal, J. Tang, p. 151
9:00 am – 9:30 am	Tribological Properties of MoS_2 & Doped-MoS_2 Spray Coatings in Low Viscosity Hydrocarbons, E. Cairns, p. 150		Endurance Testing of Cylinder Rod and Piston Seals, P. Michael, p. 151
9:30 am –10:00 am	Tribological Properties of h-BN, Ag and MgO Nanostructures as Lubricant Additives in Vegetable Oils, M. Oramas, p. 150		Radial Lip Seal Friction Torque – A Suitable Lubricant-Elastomer Compatibility Indicator?, C. Wilbs, p. 151
10:00 am – 10:30 am	Break	Break	Break
10:30 am – 11:00 am	Performance and Lubrication Mechanism of New TiO_2 Particle-Based High-Performance Lubricant Additives, F. Dassenoy, p. 150		Rheological Sealing Material, H. Xu, p. 152
11:00 am – 11:30 am	Influence of the Dispersant on the Tribological Performance of MoS_2 Nanoparticles Used as Lubricant Additives, M. Benmansour, p. 150		A Test Rig for Performance Evaluation of Dry Gas Seals with Choked Flow, P. Jolly, p. 152
11:30 am – 12:00 pm	Balance Between Zirconia Antiwear Tribofilm's Growth and Removal is Tuned via Cooperative Behavior with Co-Additives, P. LaMascus, p. 151		Tribological Challenges of High Pressure H2 Compression Using Reciprocating Industrial Compressors, T. Ozkan, p. 152
			SESSION 8C **Seals II** **Room 102A**
1:30 pm – 2:00 pm			Modelling of the Pumping Rate Behavior of Shaft Sealing Counterfaces, M. Engelfried, p. 165
2:00 pm – 2:30 pm			Experimental Study of a Reverse Pumping Spiral Groove Face Seal, A. Medjahed, p. 165
2:30 pm – 3:00 pm			Tolerance Analyses on the Geometrical Parameters of Surface Textured Seals, M. Brase, p. 165
3:00 pm – 3:30 pm	Break	Break	Break
3:30 pm – 4:00 pm			Experimental Determination of the Benefits of Textured Mechanical Seals on the Service Life of Systems, L. Amami, p. 165
4:00 pm – 4:30 pm			Measurement of Leakage and Visualization of Seal Surface of Dry Gas Seals with a Simple Inner Ring Groove, M. Ochiai, p. 165
4:30 pm – 5:00 pm			Radial Shaft Sealing System Failure Mode – Shaft Lead, A. Heinl, p. 166
5:00 pm – 5:30 pm			Seals Business Meeting

SESSION 7E Tribochemistry IV Room 102C	SESSION 7F Biotribology I Room 103A	SESSION 7G Tribotesting III Room 103B	
Tribocorrosion in FLiNaK Molten Salt, J. Qu, p. 152	Optimizing Oral Lubrication Properties of Plant Proteins by Microgelation for Improved Functionality and Fat-Replacement, B. Kew, p. 153	Development of a Novel Sled Tribometer, J. Sandberg, p. 156	**8:00 am – 8:30 am**
Ultrahigh Tribocorrosion Resistance of Metals Enabled by Nano-layering, W. Wang, p. 152	Comparing Stiffness and Lubrication Properties of Triple Network Hydrogels to PAMPS/P(NIPAAm-co-AAm) Hydrogel and Ex-Vivo Cartilage, N. Ali, p. 153	Synergistic Influence of Epoxidation and Solid Lubricant Additives Incorporation on the Lubrication Performance of Inedible Mustard Oil, S. Sikdar, p. 156	**8:30 am – 9:00 am**
Novel Tribo-Corrosion Mechanisms of Laser Shock Peened Steel Manufactured by High-Pressure Deposition Additive Manufacturing Process, A. Ralls, p. 152	Modelling the Interaction Between Skin and Products with Application to Tactile Perception, M. Masen, p. 154	In Situ Deposition of Protective Films via Metastable Additive Molecules Carried into Sliding Interfaces by Lubricant Flow, H. Wise, p. 156	**9:00 am – 9:30 am**
Mechanochemical Decomposition of Tricresyl Phosphate (TCP) Between Sliding Ferrous Surfaces, E. Ogbomo, p. 153	Development of a Synthetic Skin Test Bed for the Assessment of Beauty and Personal Care Product Consumer Experience, P. Bramley, p. 154	Ball-on-Disk Tribological Testing in the Presence of an Electric Field, S. Thrush, p. 156	**9:30 am –10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:30 am**
Aircraft Turbine Oil Antiwear Additive Reactivity with Aerospace Bearing Steels, A. Fletcher, p. 153	The Effectiveness of Chalk as a Friction Modifier for Finger Pad Contact with Rocks of Varying Roughness, K. Tomlinson, p. 154	Tribological Properties of Nanocrystalline Al-Mg Material Manufactured Using Cold Spray, A. Kushwaha, p. 156	**10:30 am – 11:00 am**
Off-Lattice Hybrid Kinetic Monte Carlo (kMC) Modeling of Film Growth at Solid-Liquid Interfaces, S. Ntioudis, p. 153	A Study on the Role of Synovial Fluid Constituents in Boundary Lubrication Mechanism at Articular Cartilage Surface, W. Li, p. 154	Tribological Performance of Aluminum Sheet Forming Lubricants, D. Sanchez Garrido, p. 157	**11:00 am – 11:30 am**
	Oral Frictional Properties of Plant and Eairy Proteins: Role of Saliva, F. Brown, p. 154	Comparison of Tribometer Reciprocating Performance Under Identical Conditions, C. Frazier, p. 157	**11:30 am – 12:00 pm**

	SESSION 8F Biotribology II Room 103A	SESSION 8G Tribotesting IV Room 103B	
	Haptic Tribometer Characterizing the Dynamic Contact Between the Human Finger and the Automotive Touchscreen, R. Shyti, p. 166	Grinding Method Process Under Lab Conditions to Evaluate Railway Microstructural Response, L. Wilches Peña, p. 168	**1:30 pm – 2:00 pm**
	Cellular Responses to Frictional Shear Stress, A. Pitenis, p. 166	Cast Iron Chef: The Final Season, A. McGhee, p. 168	**2:00 pm – 2:30 pm**
	Biotribological Characterization of the Physical Mechanisms at the Astringency Sensation Origin, I. Ammam, p. 166	Effect of Gas Environment and Test Speed on Reciprocating Wear Testing for Compressor Packing Seal Materials, J. Penaranda, p. 168	**2:30 pm – 3:00 pm**
Break	**Break**	**Break**	**3:00 pm – 3:30 pm**
	Biotribological Behavior of MXene-UHMWPE Composites, M. Marian, p. 166	Tribological Behavior of Bearing Materials in Water-Based Lubricants, J. Bosch Giner, p. 169	**3:30 pm – 4:00 pm**
	Investigating the Tribological and Corrosion Behavior of Co-Cr Alloy as an Implant Material for Orthodontic Applications, S. Saha, p. 168		**4:00 pm – 4:30 pm**
	Photo-Responsive Hydrogel Lubricity, A. Chau, p. 168		**4:30 pm – 5:00 pm**
	DECMA-1 Influence on the Mechanical and Tribological Properties of MDCK Monolayers, E. Guo, p. 168		**5:00 pm – 5:30 pm**

THURSDAY >>

TIME	SESSION 7H Commercial Marketing Forum VII Room 103C	SESSION 7I Electric Vehicles VII Room 104A	SESSION 7J Metalworking Fluids V Room 201A
8:00 am – 8:30 am	Locus Performance Ingredients – Learning to Utilize Biobased Sophorolipids in Metal Cleaning and Degreasing at Neutral pH, G. Smith, p. 157	High-Speed Elastohydrodynamic Traction and Film Thickness in Electric Vehicle Transmissions, A. MacLaren, p. 158	Advances in Bio-Based Metalworking Fluids – Addressing Formulation Challenges by Balancing the Use of Additives, L. Tekath, p. 160
8:30 am – 9:00 am	Chevron Oronite – Demonstration of H2-ICE Capable Engine Oil, D. Bansal, p. 157	Optimizing Electric Vehicle Transmission Efficiency Using a Thermally Coupled Gearbox Lubrication Model, J. Shore, p. 158	Application of High-Speed Tribology to Evaluate the Performance of Cutting Fluids on Ti-6Al-4V Under Machining Conditions, J. Secker, p. 160
9:00 am – 9:30 am	Nouryon – Nextgen Natura Derived Friction Modifiers, A. Jose Ortiz, p. 157	Study on the Discharge Behavior of EV Motor Bearings, L. Guo, p. 158	Enhancing Lubricity for Increased CGI Machining Speeds, A. Hadler, p. 160
9:30 am –10:00 am	PCC-Chemax – Novel Antiwear and Extreme Pressure Additives – A Designed Performance, D. Cooper, p. 157	Numerical Investigation of the Influence of Pitting Size on Electrical Properties of Roller Bearings, A. Zaiat, p. 158	Next-Generation Antiwear for Metalworking Fluids, L. Luz, p. 160
10:00 am – 10:30 am	Break	Break	Break
10:30 am – 11:00 am			
11:00 am – 11:30 am			
11:30 am – 12:00 pm			

TIME	SESSION 8I EV and Engine & Drivetrain VIII Room 104A
1:30 pm – 2:00 pm	Ring-Liner Testing in a Hydrogen Environment, P. Lee, p. 169
2:00 pm – 2:30 pm	The Engine Oil Effect on Fuel Economy Improvement in Different Test Types, K. Yang, p. 169
2:30 pm – 3:00 pm	Development and Testing of a Variable Hardness Piston Ring Coating for Improved Run-In, P. Lee, p. 169
3:00 pm – 3:30 pm	Break
3:30 pm – 4:00 pm	Electric Vehicle Fluid Interactions in AC and DC Environments, A. Velasquez, p. 169
4:00 pm – 4:30 pm	High-Temperature Thermoplastics in Electric Drivetrain Bearings, K. Farokhzadeh, p. 169
4:30 pm – 5:00 pm	How to Improve Engine Lifetime by Use of Premium Fuel, N. Doerr, p. 170
5:00 pm – 5:30 pm	Novel Sustainable Low-Viscosity Synthetic Base Fluids for E-Mobility, M. Liang, p. 170
5:30 pm – 6:00 pm	High Performance Synthetic Lubricants Designed for High-Speed e-Mobility Application, P. Ma, p. 170

SESSION 7K Surface Engineering III Room 201B	SESSION 7L Grease III Room 202A	SESSION 7M Wear II Room 202B	
		New Amine Phosphate Esters as Multifunctional Antiwear Additives, J. Dixon, p. 164	8:00 am – 8:30 am
	Grease Patterns After Rolling Contact, H. Qi, p. 162	RNT Wear Testing with Ultra-Low Viscosity Engine Oil on Full Bench Engine, M. Eggenstein, p. 164	8:30 am – 9:00 am
Making Surface Texture Meaningful: Case Studies in Surface Analysis for Tribological Applications, M. Malburg, p. 162	Dissipative Particle Dynamics Simulations of Thickener Fiber Formation Process and Behavior Under Shear Flow, H. Yanagisawa, p. 163	Wear of Aerospace Bearing Steels in Lubricated Reciprocating Tribotesting, M. Kirsch, p. 164	9:00 am – 9:30 am
How Can We Avoid PET Bottle Pile-Ups During Conveying by Better Understanding Friction and Adhesion Phenomena?, E. Georgiou, p. 162	Visualization of Grease Fluidity in a Ball Bearing Using Neutron Imaging Technology, K. Sakai, p. 163	The Use of the MTM Rig for Wear Testing, M. Smeeth, p. 164	9:30 am –10:00 am
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Tribology: Adhesion, Friction, and Socioeconomy, P. Tomar, p. 162	Analyzing Wear and Additive Elements in Greases: XRF, RDE-OES or ICP-OES?, C. Rohbogner, p. 163	Effects of Trace Moisture Content on Tribo-Film Formation, Friction and Wear of CF-Filled PTFE in High-Purity Hydrogen, Q. Chen, p. 164	10:30 am – 11:00 am
Stick-Slip Friction: Mechanics, Mechanism, and Electroadhesion, P. Tomar, p. 152	Effect of Oxidation on the Lubricating Performance of Greases, G. S. Dodos, p. 163	Enhanced Metal Corrosion of Long-Life Antifreeze Coolants, H. Gao, p. 164	11:00 am – 11:30 am
	Film Thickness in Grease Lubricated Bearings: Effects of Grease Filling, Bearing Size and Grease Properties, P. Shetty, p. 163	Local Contact Pressure Governs Mild Wear Mechanisms at Multi-Asperity Interfaces, C. Leriche, p. 165	11:30 am – 12:00 pm

	SESSION 8L Grease IV Room 202A	SESSION 8M Wear III Room 202B	
	Quantum-Leap Grease Formulation Through Preform Chemistry, N. Iderkou, p. 170	An Investigation into the Tribological Performance of Wear Resistant PVD Coatings . . . , R. Lal, p. 171	1:30 pm – 2:00 pm
	Best Practices for Making Urea Grease from a Powdered Thickener, L. Huffman, p. 170	. . . Characteristics of Pitch & Poly-acrylonitrile-Based Carbon-Carbon Composites in Air and Nitrogen Environment Under Aircraft Taxi Conditions, A. Sharma, p. 171	2:00 pm – 2:30 pm
	Influence of Grease Thickener Types on the Film Formation, T. Kamihata, p. 170	Wear Characteristics of ZDDP Tribofilm, A. Fome, p. 171	2:30 pm – 3:00 pm
Break	Break	Break	3:00 pm – 3:30 pm
	Evolution of an Advanced Method for Characterization of Thermo-Oxidative Grease Failure, M. Matzke, p. 171		3:30 pm – 4:00 pm
	Oxidation and Grease Life in Rolling Bearings, P. Lugt, p. 171		4:00 pm – 4:30 pm
			4:30 pm – 5:00 pm
			5:00 pm – 5:30 pm

Session 7A | 101A

Lubrication Fundamentals VII: Nanoparticles and Coatings

Session Chair: Abhishek Kumar, University of California, Merced, Merced, CA

Session Vice Chair: Ramoun Mourhatch, Chevron Oronite LLC, Richmond, CA

8:00 am – 8:30 am

3831473: Influence of Lubricant Additive Urea-ZrP on Viscosity

Kailash Arole, Yan Chen, Adolfo Delgado, James Hubbard, Hong Liang, Texas A&M University, College Station, TX

Understanding the effects of functionalized nanoparticles on viscosity is fundamentally important to develop novel lubricants. In this research, we investigate the two-dimensional (2D) nanop0articles Zirconium phosphate (α -ZrP) functionalized by urea. Fluidic behavior was studied focusing on viscosity. Experiments were conducted using a rheometer with applied electric field. Results showed that the addition of nanoparticles reduced fluid shear and viscosity. While applying an electric field, viscosity further changed, i.e., increase.? Analysis indicated that the generation of dipoles in urea modified ZrP particles was responsible for the increase. Such change is attributed to the reorganization of those particles after applying the electric field. This presentation discusses the details of the alteration and principles behind it.

8:30 am – 9:00 am

3805242: Macro Topography Effect on Friction in Presence of Surface Textures in Conformal Contacts

Gerda Vaitkunaite, Erik Hansen, Johannes Schneider, Bettina Frohnapfel, Peter Gumbsch, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Surface textures have a proven effect on extending hydrodynamic regime features in mixed lubrication by improving load carrying capability of lubricant flow. However, the complex multi-physics and multi-scale interactions of textures in conformal contacts are not fully understood. Macrogeometry effects are often left out of consideration in the literature, even though their characterization is essential for the friction behavior. Thus, in this work, we propose pathways to control and observe macro topography features (waviness, pitch angle, curvature) and surface texturing effects on the Stribeck curve. The experimental pin-on-disk tribometer findings indicate that the combination of these effects can reduce friction up to 60% in the mixed lubrication regime. The experimental observations are extended by the numerical model presented in the abstract 3804989, which gives a new insight into a reproducible and robust design of macro topography and surface textures in conformal contacts.

9:00 am – 9:30 am

3824576: Tribological Properties of MoS_2 & Doped-MoS_2 Spray Coatings in Low Viscosity Hydrocarbons

Euan Cairns, Samir Aouadi, Diana Berman, Andrey Voevodin, University of North Texas, Denton, TX; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Emerging low carbon emission fuels, such as ethanol and synthetics, lead to a growing need for materials that can increase wear life of fuel pump components. Solid lubricants, such as molybdenum disulfide (MoS_2), can provide excellent tribological properties under specific environmental conditions. Previously, MoS_2 was found to have potential to be used, as a protective coating, in low viscosity hydrocarbon fuels. A coefficient of friction of less than 0.1 was seen in dodecane (a synthetic surrogate) and maintained for 100 m of sliding, whereas in ethanol, fast coating failure occurred. In this report, we show incorporation of dopant particles improves resistance of MoS_2 to failure in ethanol, where a low coefficient of friction is maintained for the duration of the test. Analysis of wear tracks and counterbody scars were performed using profilometry, optical microscopy, Raman and X-ray photoelectron spectroscopy, possible lubrication mechanisms are discussed.

9:30 am – 10:00 am

3834300: Tribological Properties of h-BN, Ag and MgO Nanostructures as Lubricant Additives in Vegetable Oils

Maria Victoria Granja Oramas, C. Fred Higgs III, Rice University, Houston, TX; Kollol Jogesh, Jaime Taha, University of Texas Rio Grande Valley, Edinburg, TX

There exists an ever-growing need for sustainable engineering solutions to improve emission control and energy efficiency of tribosystems. This study examines the tribological properties of two environmentally friendly oils, soybean and sunflower oil, with the addition of three different non-toxic nanostructures (h-BN, silver and MgO) at different concentrations. The friction and wear preventive properties of the mixtures are studied using a four-ball tribometer. The experimental results show that nanoparticles, added to vegetable oils at specific concentrations, exhibit good friction-reduction and anti-wear properties. The best operating mixtures are further studied after the tribological tests using an optical microscope, SEM, and EDX to elucidate the possible mechanisms of anti-friction and anti-wear when using the different nanoparticles.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3811476: Performance and Lubrication Mechanism of New TiO_2 Particle-Based High-Performance Lubricant Additives

Fabrice Dassenoy, Sophie Pavan, Galipaud Jules, LTDS/ECL, Ecully, France; Istvan Jenei, Stockholm University, Stockholm, Sweden; Stephan Wieber, EVONIK, Darmstadt, Germany

There has been growing interest in nanoparticles for tribological applications over the past 20 years. Studies have shown their remarkable lubricating properties, namely friction-reduction and anti-wear, especially when used as lubricant additives. TiO_2 nanoparticles present several advantages. In addition to be easy to produce and to have low preparation cost, they provide good anti-wear properties to the lubricant in some conditions where the performance of other additives are sometimes limited. In this work, the tribological performance of new TiO_2 particle based lubricant additives are presented. The tribofilms generated during the friction tests were characterized using X-Ray Photoelectron Spectroscopy (XPS) and Transmission Electron Microscopy (TEM). The way the TiO_2 nanoparticles additives behave and offer surface protection against boundary contact will thus be discussed.

11:00 am – 11:30 am

3806344: Influence of the Dispersant on the Tribological Performance of MoS_2 Nanoparticles Used as Lubricant Additives

Marina Benmansour, Fabrice Dassenoy, Jules Galipaud, Beatrice Vacher, LTDS/ECL, Ecully, France; Pavel Afanasiev, IRCE Lyon, Lyon, France; Lucile Joly-Pottuz, INSA Lyon, Lyon, France

Nanoparticles (NPs) are interesting lubricant additives to reduce friction. Their sizes allow them to enter easily in the contact. They are also much less chemically reactive than molecular additives. Sulfides NPs exhibit the highest friction and wear reduction. In this work, MoS_2 NPs have been studied in a PAO base oil. Excellent friction reduction properties were

observed at low temperature. However, at high temperature, the Brownian movement is amplified. The nanoparticles leave the contact and their tribological performance are degraded. Thereby, a PIB succinimide dispersant was added. This study aims to evaluate the influence of dispersant on the tribological properties of MoS_2 NPs. Tribological tests were carried out in boundary lubrication regime. Morphological and chemical analysis were made to correlate tribofilm composition, tribological performance and tests conditions. Our study reveals that the dispersant still permits the friction reduction at high temperature.

11:30 am – 12:00 pm

3813207: Balance Between Zirconia Antiwear Tribofilm's Growth and Removal is Tuned via Cooperative Behavior with Co-Additives

Parker LaMascus, Daniel Delghandi, Pranjal Nautiyal, Andrew Jackson, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Meagan Elinski, Hope College, Holland, MI; Julia Griffin, Mount Holyoke College, South Hadley, MA; Lei Zheng, Robert Wiacek, Pixelligent, LLC, Baltimore, MD

Anti-wear additives permit energy efficient lubrication in gearboxes, bearings, and other tribological interfaces. We study ZrO_2 nanocrystals, which form anti-wear tribofilms in sliding regions. We extend prior work by examining the growth kinetics of ZrO_2 tribofilms with and without S- and P-based co-additives at a variety of realistic slide-roll-ratios. In a Mini Traction Machine (MTM) tribometer, we observe that ZrO_2 tribofilm growth is often interrupted, highlighting a competition between tribofilm growth and removal processes. When ZrO_2 is dispersed alongside co-additives, tribofilm removal intensifies, leading to a smoother morphology once the tribofilm thickness saturates. Since we also tend to observe lower traction when co-additives are present, we posit that smoother tribofilms contribute to greater surface separation. We also find that increased sliding speeds promote faster ZrO_2 tribofilm growth per cycle of contact, as does the presence of co-additives.

Session 7C | 102A

Seals I

Session Chair: Paul Michael, Fluid Power Institute, Milwaukee School of Engineering, Milwaukee, WI

Session Vice Chair: Hanping Xu, Ultool, LLC, Duluth, GA

8:00 am – 8:30 am

3812275: Modeling and Simulation of the Dynamic Sealing and Lubrication Mechanism of Rotary Shaft Seals

Jeremias Grün, Simon Felmeth, Frank Bauer, University of Stuttgart, Stuttgart, Germany

Rotary shaft seals are machine elements subjected to high dynamic loads. Their main task is to prevent undesirable fluid exchange between two areas. On gearboxes, for example, they prevent transmission oil from leaking into the ambient air. If the effect of cavitation is considered, a multiphase flow consisting of the three phases oil, oil vapor and air occurs in the sealing gap. The fluid flow characteristics vary with time and with speed. The aim of this contribution is to present modeling approaches and simulation methods for the computation of the transient multiphase flow in the sealing gap. This comprises the multiscale structural mechanical effects and the microscopic transient fluid flow processes in operation. Finite element analyses are applied to solve the structural mechanics. The flow processes are solved with computational fluid dynamics. Furthermore, experimental approaches for the verification and validation of the presented methods are discussed.

8:30 am – 9:00 am

3831169: A Secondary Self-Opening Start-Up Clearance Seal

Jing Tang, Hanping Xu, Ultool LLC, Duluth, GA; Sevki Cesmeci, Fuad Hassan, Georgia Southern University, Statesboro, GA

The start-up of pressure-generating systems, such as turbines, or other pressurization systems that provide stable pressurized fluid to downstream processes, relies on effective sealing, which in turn is affected by operational pressures. During prolonged start-up, the fluid leakage will result in inefficiency, contamination, and working fluid loss. A secondary self-opening startup clearance seal is proposed that includes a sleeve with a lip around an axis of rotation. The sleeve lip has zero or minimal clearance to the shaft at start-up, which helps increase the pressure of the pressures generating fluid system and can deform at nominal system pressure to create openings to eliminate friction and wear. The addition of secondary self-opening start-up clearance seal can shorten start-up time, reduce leakage and improve energy efficiency.

9:00 am – 9:30 am

3834075: Endurance Testing of Cylinder Rod and Piston Seals

Paul Michael, Fluid Power Institute, Milwaukee School of Engineering, Milwaukee, WI

Hydraulic cylinders convert the flow produced by a positive displacement pump into mechanical energy in the form of linear velocity and force. Long life can be achieved by cylinders when losses due to seal leakage are minimized. Control of leakage losses in cylinders requires an understanding of piston and rod seal wear. Piston and rod seal test rigs were constructed to permit the simultaneous evaluation of up to 16 single-acting rod seals and 4 double-acting piston seals. Endurance tests were conducted at high temperatures. Most seals showed minimal deterioration in leakage control throughout the duration of testing. When leakage occurred, it was associated with seal extrusion. Rod seal extrusion produced external leakage. Piston seal extrusion caused internal leakage and loss of cylinder position control. Seal lip profile and surface roughness were found to affect leakage. These findings are useful for improving the reliability and durability of hydraulic cylinders.

9:30 am – 10:00 am

3849023: Radial Lip Seal Friction Torque – A Suitable Lubricant-Elastomer Compatibility Indicator?

Christian Wilbs, Daniel Froelich, Matthias Adler, Freudenberg FST GmbH, Weinheim, Germany

The radial shaft seal (RSS) is a widely used machine element, e.g., in electric drive units or gearboxes in wind turbines to seal lubricants against the environment. Downtimes due to maintenance or even leakages must be avoided as far as possible. In particular, the complex interactions between the lubricant to be sealed and the radial shaft seal have a major influence on the reliability and service life of a radial shaft sealing system. It is therefore essential to ensure lubricant-elastomer compatibility under dynamic tribological stress by dynamic tests. The post-test analyses, e.g., seal wear or changes in material properties, provide information on the lubricant-elastomer compatibility. One possibility is the evaluation of the friction torque of the radial shaft sealing system. The paper presented here is to show how the friction torque measurements correlate with the damage mechanisms due to an existing incompatibility and how to predict the compatibility based on the friction.

10:00 am – 10:30 am – Break

7C

10:30 am – 11:00 am

3833033: Rheological Sealing Material

Hanping Xu, Jing Tang, Aaron Harcrow, Ultool, LLC, Duluth, GA; Jacqueline Johnson, Leonard Lee, Sharon Gray, Terekhov Yuryevich, UTSI, Tullahoma, TN

A rheological seal material is introduced that operates in high temperature applications. It is solid under installed conditions and flows at a threshold pressure. The stress inside the rheological seal material gradually decreases from system pressure to ambient pressure. It neither creeps nor sticks, is flexible to accommodate deformed sealing surfaces, fills microgrooves while maintaining contact for an effective seal, resists damage when rubbed on rough sealing surfaces without unduly increasing leakage due to wear. A test rig was built to detect leakage through a rheological gasket into a vacuum chamber. The results show that the rheological gasket can effectively seal helium at 400°C. Further material analysis reveals that the rheological gasket is stabilized at 1200°C, after 6~8% weight loss. Potential applications include, but are not limited to, sealing applications at temperatures above 400°C. Distribution is unlimited/ AFRL-2022-5168; Cleared 10/26/2022.

11:00 am – 11:30 am

3833540: A Test Rig for Performance Evaluation of Dry Gas Seals with Choked Flow

Pascal Jolly, Noel Brunetiere, Institut Pprime – CNRS – Université de Poitiers, Chasseneuil du Poitou, France

The present paper describes the design, construction and commissioning of a test rig dedicated to dry gas lubricated mechanical face seals. It is mainly composed of a 15kW electrospindle connected to a test cell via a torque meter. The maximum rotational speed is 60 krpm. It can operate with compressed air and a pressure differential up to 15MPa. The architecture of the test cell is based on an overhung rotor, supported by two high precision ball bearings, lubricated with grease. Two similar seals are tested in a back-to-back arrangement, with see-through rotating rings for infrared thermography. The stationary rings are textured and made of tungsten carbide. Their inner and outer diameters are 50mm and 64mm respectively. The test cell is equipped with many sensors. Thus, the performance of dry gas seals can be evaluated in severe operating conditions, for instance choked flow condition. The first results are presented.

11:30 am – 12:00 pm

3834144: Tribological Challenges of High Pressure H2 Compression Using Reciprocating Industrial Compressors

Tanil Ozkan, Jonathan Penaranda, Dover Innovation Laboratory, Houston, TX; Burak Bekisli, Dover Precision Components, Woodlands, TX

Safe and cost-efficient gas compression is essential in many industries and hydrogen is expected to have increased market share, as a consequence of decarbonization and sustainability trends in the emerging global energy economy. This presentation discusses the tribological challenges of high pressure H2 compression using reciprocating industrial compressors with special emphasis on high-performance engineering polymers and their composites employed as packing case and cylinder sealing components. Physical, mechanical, thermodynamical and tribochemical aspects of high pressure and high temperature hydrogen environment are considered from a technical perspective. Risk factors and special attributes directly associated with the use of hydrogen such as self-limiting diffusion, voiding, embrittlement, reducing gas effects, rapid depressurization and negative Joule-Thomson effect are also included in this discussion.

Session 7E | 102C

Tribochemistry IV

Session Chair: Nikhil Murthy, US DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Session Vice Chair: TBD

8:00 am – 8:30 am

3808686: Tribocorrosion in FLiNaK Molten Salt

Jun Qu, Xin He, Chanaka Kumara, Dino Sulejmanovic, James Keiser, Nidia Gallego, Oak Ridge National Laboratory, Oak Ridge, TN

In a molten salt reactor, the carbon-encapsulated fuel pebbles that would inevitably contact the reactor's stainless steel (SS) container wall during salt circulation, causing safety concern. In this study, tribocorrosion behavior of graphite sliding against 316H SS in a molten FLiNaK salt was investigated using a bench-scale tribometer. Accelerated wear loss was observed at a higher temperature because of a lower molten salt viscosity and a higher corrosion rate. A salt-starved condition produced more material loss than either the no-salt or the salt-flooded condition because neither a stable tribofilm nor a transfer film could be established in salt-starved conditions, leading to poor wear performance. Surface characterization revealed a chromium-rich top film and a nickel-accumulated but chromium-depleted interlayer on the SS surface inside the wear track, which is distinct from the molten salt–corroded SS surface that experiences chromium depletion as reported in the literature.

8:30 am – 9:00 am

3833050: Ultrahigh Tribocorrosion Resistance of Metals Enabled by Nano-layering

Wenbo Wang, Oak Ridge National Laboratory, Knoxville, TN

Nanostructured metallic multilayers (NMMs) offer great opportunity to simultaneously improve wear and corrosion resistance of metals. In this work, the wear, corrosion and tribocorrosion resistance of NMMs of Al/X (X= Mg, Cu, and Ti) were evaluated through experiments, finite element simulations, and density functional theory calculations. Transmission electron microscopy of deformed and degraded sample surfaces showed characteristic different deformation and degradation mode of all samples, governed by the synergistic effects of the mechanical and corrosion properties of the constituting materials. A finite element based computational model was developed to study the effects of constituting material on the material loss rate under various external mechanical and chemical loads. Finally, density functional calculations provide further insight on the material selection and design criteria for metallic multilayers toward enhanced performance under extreme environment.

9:00 am – 9:30 am

3836499: Novel Tribo-Corrosion Mechanisms of Laser Shock Peened Steel Manufactured by High-Pressure Deposition Additive Manufacturing Process

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

The utilization of cold spray (CS) has greatly reduced the dilapidation of mechanical components used in mechanical assemblies. However, due to the non-uniform deformation of the accelerated particles, defects in the form of voids are quite common. As such, their performance is limited, especially when exposed to chemical-abrasion environments. This creates a need to understand their wear-corrosion mechanisms and how they can be essentially improved. In this work, we study the tribo-corrosion mechanisms of CS coatings and understand how their change in interparticle bonding mechanics can improve their tribo-corrosion performance. By subjecting these coatings to laser shock peening (LSP), it was found that the combination of surface densification and hardness

greatly reduced its wear loss. As such, it was determined that LSP is indeed a viable technique for post-process modification. The critical and novel changes in tribo-corrosion mechanisms were also identified and elucidated.

9:30 am – 10:00 am

3849044: Mechanochemical Decomposition of Tricresyl Phosphate (TCP) Between Sliding Ferrous Surfaces

Egheosa Ogbomo, Imperial College London, London, United Kingdom

Studies have shown that the major component of the tribofilms formed from TCP on steel is iron phosphate, which acts as a protective layer rather than polishing the rubbing surfaces. It has also been shown that organic polyphosphate or iron polyphosphates are eventually formed from TCP inside tribological contacts and are ultimately responsible for its antiwear performance on steel surfaces. At high temperature, TCP forms relatively thick (60–100 nm) thermal films on steel surfaces, but thinner tribofilms are usually formed inside rubbing contacts. This project has studied the mechanochemical decomposition of TCP being sheared between two ferrous surfaces (of varying chemistries) using LAMMPS and the ReaxFF force field to attempt to quantify the effects of shear stress and surface chemistry on the formation of the afore-mentioned tribofilms. The simulation conditions have ranged from 1-5 GPa, 300- 700 K, at sliding speeds between 10m/s and 50m/s.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3834074: Aircraft Turbine Oil Antiwear Additive Reactivity with Aerospace Bearing Steels

Alexander Fletcher, Mathew Kirsch, Daulton Isaac, Patrick Hellman, Air Force Research Laboratory, WPAFB, OH; Daesung Chong, University of Dayton Research Institute, Dayton, OH

Phosphate based antiwear additives are commonly found in aircraft turbine oils. These additives provide critical protection for engine mechanical components, such as bearings, in the mixed and boundary lubrication regimes by the formation of a protective tribofilm. One factor influencing tribofilm formation is the steel composition. Previous research indicated that certain bearing steels may be less reactive with phosphate additives leading to an increase of wear in non-EHL regimes. This study examines the reactivity of phosphate antiwear additives with various materials by measuring the post-test antiwear additive concentration. A turbine oil basestock was additized with phosphate antiwear agents. These fluids and the select bearing steels were subjected to long duration sliding-wear experiments inducing triboflim formation and antiwear additive consumption. By measuring the depletion of the additives, the rate of tribofilm formation on the bearing steels can be determined.

11:00 am – 11:30 am

3833624: Off-Lattice Hybrid Kinetic Monte Carlo (kMC) Modeling of Film Growth at Solid-Liquid Interfaces

Stavros Ntioudis, James Ewen, Daniele Dini, Imperial College London, London, United Kingdom; C. Turner, University of Alabama, Tuscaloosa, AL

Antiwear additives contained in lubricants form protective thin films on rubbing interfaces. Such films prevent direct metal-to-metal contact and contribute to the reliable operation of critical modern engineering systems (e.g., engines). The numerical investigation of protective thin films demands a theory capable of capturing significant atomistic processes (e.g., reactions, diffusion, adsorption). Nonetheless, it becomes computationally intractable to deploy methods of atomic level resolution (i.e., ab-initio or bond-order based) to study the properties of thin films beyond the early stages of growth. In this work, we present a hybrid off-lattice kinetic Monte Carlo (kMC) framework that promises to extend the simulation timescales beyond the nanosecond and up to the second/minute timescales. The novel modeling framework is used to study the long timescale morphological as well as structural/chemical properties of thermally grown tricresyl phosphate films on pristine iron surfaces.

Session 7F | 103A

Biotribology I

Session Chair: Marc Masen, Imperial College of London, London, United Kingdom

Session Vice Chair: Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA

8:00 am – 8:30 am

3832881: Optimizing Oral Lubrication Properties of Plant Proteins by Microgelation for Improved Functionality and Fat-Replacement

Ben Kew, Melvin Holmes, Evangelos Liamas, Anwesha Sarkar, University of Leeds, Leeds, Yorkshire, United Kingdom

With the resource-intense meat industry accounting for over 50% of food manufacturing emissions, plant protein consumption is an inevitable need of the hour. Despite its significance, the barrier to adoption of plant proteins is their off-mouthfeel, associated with high friction and consequently poor lubrication performance. We demonstrate that by transforming plant proteins into physically crosslinked microgels, it is possible to improve their lubricity enormously, evidenced by tribology using biomimetic tongue-like surface with atomic force microscopy, dynamic light scattering, rheology and adsorption measurements (QCM-D). Unprecedented findings supported by numerical modelling reveal that these non-lipidic microgels not only decrease friction in the boundary regime by an order of magnitude compared to native protein but also replicate the lubrication performance of high fat emulsions, thus pave a unique platform in designing next generation healthy, palatable, sustainable foods.

8:30 am – 9:00 am

3834114: Comparing Stiffness and Lubrication Properties of Triple Network Hydrogels to PAMPS/P(NIPAAm-co-AAm) Hydrogel and Ex-Vivo Cartilage

Nabila, Ali, Alison Dunn, University of Illinois at Urbana-Champaign, Urbana, IL, Connor Demott, Melissa Grunlan, Texas A&M University, College Station, TX

Earlier double network hydrogels (DN hydrogels) showed great potential for replacing cartilage. To explore that potential further, we discuss the frictional properties and stiffness of four triple-network hydrogels (TN hydrogels). The first and second networks of all the TN hydrogels are the same as the PAMPS/P(NIPAAm-co-AAm)(DN-AAm) hydrogel. They have four different co-monomers- PAAm (neutral), PAMPS (anionic), PAPTAC (cationic), and PMEDSAH (zwitterionic) as the third network. We compare the stiffness and frictional properties of the TN hydrogels, DN-AAm hydrogel, and cartilage samples. All TN hydrogels show greater elastic modulus than the DN-AAm hydrogel but lower than the cartilage samples except for TN-APTAC hydrogel (1437 kPa). Generally, in both DI water and FBS, the TN hydrogels exhibit a lower friction coefficient than DN-AAm hydrogel and cartilage. These results indicate that the hydrogels' stiffness and frictional properties are controlled by the final network.

7F

9:00 am – 9:30 am

3848864: Modelling the Interaction Between Skin and Products with Application to Tactile Perception

Marc Masen, Imperial College of London, London, United Kingdom

As we interact with objects and surfaces, mechanical stimuli propagate from the skin surface towards the mechanoreceptors, causing neurological signals to be sent to the central nervous system thus initiating a psychological and behavioral response. Cutaneous biotribological phenomena are currently not fully understood, and in this work, we present a numerical model aimed at better understanding tactile perception. This model simulates skin-surface interaction and the transmission of stresses, strains and energy to the tactile mechanoreceptors. The model was used to study a range of scenarios, including the touch-perception of textured surfaces and polymeric films. Touch of textured surfaces is strongly affected by the mechanical interlocking of textures with the fingerprint ridges. In the case of polymer films produce a specific tactile response depending on their adhesive properties, and in special cases stick-slip-like behavior is observed.

9:30 am – 10:00 am

3810768: Development of a Synthetic Skin Test Bed for the Assessment of Beauty and Personal Care Product Consumer Experience

Phoebe Bramley, University of Sheffield, Sheffield, United Kingdom

Beauty and personal care (BPC) products such as moisturizers can play a crucial role in maintaining skin health, treating various skin conditions and for aesthetics. Consumer preferences are widely driven by perceived sensory attributes, e.g., tactile or smell, whether this be during the opening of the product, or during application and drying. Understanding what determines the success of a product in terms of sensory perception therefore constitutes an essential part in the development of skin care products. In this project, a hydrophilic artificial skin model with the topography of human forearm skin was developed. The effect of skin texture, surface energy and hydration on the friction of dry and cream treated skin were evaluated, as well as the effect of time following cream treatment. Results were plotted against attribute ratings obtained through sensory panels, to identify trends and understand the role different skin properties play in the sensory perception of BPC products.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3812383: The Effectiveness of Chalk as a Friction Modifier for Finger Pad Contact with Rocks of Varying Roughness

Katherine Tomlinson, Ben Clarke, Tom Slatter, Roger Lewis, Matt Carre, University of Sheffield, Sheffield, United Kingdom

The application of chalk (magnesium carbonate) in rock climbing is common practice as climbers attempt to improve their grip by removing moisture from their hands with the aim of increasing friction at the finger-rock interface. This study investigated the effectiveness of chalk as a friction modifier by considering a range of rocks in combination with both dry and moist finger pads. The influence of load and surface roughness were considered by using a selection of different rocks (including sandstone, granite, limestone and carboniferous limestone) and a range of normal loads (5N, 10N and 15N). Preliminary results indicate that powdered chalk increases the friction for all finger pad contact with granite and dry finger pad contact with sandstone and limestone, however this increase in friction is not observed when contact is made with carboniferous limestone. This suggests that climbers should observe the rock type and humidity levels when considering the use of chalk in climbing.

11:00 am – 11:30 am

3832875: A Study on the Role of Synovial Fluid Constituents in Boundary Lubrication Mechanism at Articular Cartilage Surface

Wenxiao Li, Takehiro Morita, Yoshinori Sawae, Kyushu University, Fukuoka, Japan

To clarify the role of synovial fluid constituents in boundary lubrication mechanism existing at the articular cartilage surface, the angularly reciprocating tests with a spherical glass probe and fresh articular cartilage specimens were performed over a range of sliding speeds and extremely low contact loads. The contact pair was lubricated with different lubricants containing proteins, hyaluronic acid, and phospholipids as representative synovial fluid constituents to evaluate the lubrication ability of each constituent. Two different treatments: gentle washing with detergent and incubation in NaCl solution were applied to cartilage specimens to remove certain constituents and examine synergistical effects of synovial fluid constituents and the superficial area of articular cartilage. Results of the friction test indicated that serum proteins have an important role to reduce and stabilize the friction under the boundary lubrication condition.

11:30 am – 12:00 pm

3818435: Oral Frictional Properties of Plant and Eairy Proteins: Role of Saliva

Fran Brown, Alan Mackie, Anwesha Sarkar, University of Leeds, Leeds, United Kingdom; Qi He, Jochen Pfeifer, Mondelez International, Reading, United Kingdom

Creamy mouthfeel is often an important sensory attribute in confections, dairy products, sauces, etc. that controls consumer acceptability. Protein fortified food is known to generate undesirable 'dry' mouthfeel, which is more prominent in plant proteins. In vitro techniques using tribology show that 'dry' mouthfeel is linked to lubrication failure. This study used soft tribology to compared boundary friction properties of plant and dairy proteins in both the absence and presence of model saliva (protein: model saliva ratio: 4:1 w/w) to provide a physical mechanism behind such dry perception. Tribo-contact surfaces were glass-polydimethylsiloxane (PDMS) and QCM-D using PDMS-coated sensors and rheology data were used to contextualize results. Results indicated that tribological behavior is largely dictated by the proteins in contact, with addition of saliva only contributing to the dilution affecting mixed lubrication irrespective of the type of proteins.

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Session 7G | 103B

Tribotesting III

Session Chair: Soumya Sikdar, University of Nevada, Reno, Reno, NV

Session Vice Chair: Alessandro Ralls, University of Nevada, Reno, Reno, NV

8:00 am – 8:30 am

3833790: Development of a Novel Sled Tribometer

Joakim Sandberg, Kalle Kalliorinne, Gustav Hindér, Andreas Almqvist, Hans-Christer Holmberg, Roland Larsson, Luleå University of Technology, Luleå, Sweden

Measurements of ski-snow friction is a delicate task due to the nature of snow and the ever-changing environment. In addition, the friction is low, and the equipment must be highly sensitive. Previous works report on tests ranging from small-scale model experiments performed in lab environment to experiments with full-sized skis outdoors. However, not many come close to replicating authentic conditions present during skiing. A novel sled tribometer was developed and the repeatability was evaluated using full-sized skis gliding at relevant speeds (~30 km/h) in a controlled environment indoors. The precision was determined adequate to differentiate between different ski-base structures and preparations. The precision is affected by vibrations induced by launching the sled. Fortunately, the problem can be reduced by launching the sled at a higher speed, and then allowing it to stabilize during deceleration before sampling the data used for analysis.

8:30 am – 9:00 am

3833407: Synergistic Influence of Epoxidation and Solid Lubricant Additives Incorporation on the Lubrication Performance of Inedible Mustard Oil

Soumya Sikdar, Md Hafizur Rahman, Pradeep Menezes, University of Nevada, Reno, Reno, NV

The trend of employing inedible plant-based oils as a base stock for bio-lubricant is rising due to the depletion of fossil fuels and environmental issues. Inedible mustard seed oil is abundantly available for bio-lubricant oil production. However, this oil suffers from poor oxidation stability. This research investigated the modification in inedible mustard oil's lubrication performance by epoxidation reaction as well as the incorporation of two solid lubricant additives namely graphene nanoplatelets (GNP) and hexagonal boron nitride (hBN) to form nano lubricants. These nano lubricants were evaluated for viscosity, presence of different functional groups, wettability, friction, and wear properties. The boundary lubrication regime was chosen for the friction and wear properties. The results from these properties showed improved lubrication performance of the mustard oil that could help in better energy conservation.

9:00 am – 9:30 am

3834203: In Situ Deposition of Protective Films via Metastable Additive Molecules Carried into Sliding Interfaces by Lubricant Flow

Harry Wise, Tobias Martin, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Jack Loken, University of Wisconsin-Madison, Madison, WI

Cyclopropanecarboxylic-acid (CPCa), a surface-active, metastable additive, increases the rate of polymerization of hydrocarbon fluids at asperity contacts. Earlier investigations reduced wear on 52100 steel by introducing CPCa in polyalphaolefin (PAO-4). We explore how CPCa dissolved in dodecane, a liquid less viscous than PAO-4, impacts its wear protection on 52100 and D2 steel. Under pin-on-disk tribotesting for CPCa in dodecane, the wear coefficient for D2 is less than that for 52100. We attribute D2's performance to oligomeric/polymeric films catalyzed by more abundant surface chromium oxide. These films reduce wear when CPCa is removed. After tribotesting for 15 minutes with CPCa dissolved in dodecane, then replacing the fluid with pure dodecane, the wear coefficients of 52100 and D2 are less than that for each steel in dodecane for up to 30 and 75 minutes respectively. These observations suggest in-situ CPCa treatment as a strategy for wear protection during boundary lubrication.

9:30 am – 10:00 am

3834073: Ball-on-Disk Tribological Testing in the Presence of an Electric Field

Steven Thrush, Allen Comfort, James Dusenbury, US Army DEVCOM GVSC, Warren, MI

A ball on disk tribometer was augmented with a potentiostat enabling surface potential control to generate an electric field. The disk acts as the working electrode. The platinum wire counter electrode is held in place by a 3D printed ring of an electrically insulative material around the perimeter inside the oil cup. A reference electrode is placed between the working and counter electrode to monitor the electrochemical potential enabling precise control of surface potential. Esters with supporting electrolyte and friction modifiers were used to validate the experimental setup. Under certain surface potentials, friction reductions of as much as 70% were observed and active control of friction performance was achieved by adjusting surface potential. Stribeck curves were generated to understand the lubrication regimes of best performance in the presence of an electric field. Boundary lubrication tests were conducted to test the robustness of formed adlayers.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3834311: Tribological Properties of Nanocrystalline Al-Mg Material Manufactured Using Cold Spray

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

In the present work, nanocrystalline (NC) pure Al and Mg-doped Al materials were manufactured using cryomilling followed by a high-pressure cold spray (HPCS) process. The changes in the crystallite size of the milled powders and bulk samples were determined using the X-ray diffraction technique. The hardness tests of the bulk samples were carried out using a Vickers microhardness tester. Tribological properties were studied using a tribometer. The XRD analysis showed a decrease in crystallite size with increasing cryomilling time. This reduction in crystallite size resulted in increased hardness of the material. The increase in hardness produced a lower coefficient of friction and wear rate. The Mg-doped Al material showed superior hardness and tribological properties compared to the pure Al. The underlying mechanisms for the decrement in crystallite size and its effect on hardness, friction, and wear performance will be discussed.

11:00 am – 11:30 am

3834315: Tribological Performance of Aluminum Sheet Forming Lubricants

Daniel Sanchez Garrido, Novelis, Kennesaw, GA

Lubrication is an essential aspect of sheet metal forming. Currently, forming lubricants have mainly been developed for steel applications. However, as rolled sheet aluminum forming becomes more relevant in the automotive industry, it is important to characterize forming lubricants (current and new products specially developed for aluminum) to better understand their performance and compatibility. Here, various forming lubricants were applied on mill finish and textured aluminum sheets to characterize their tribological performance by measuring forming loads, friction, and surface evolution over a range of pressures. Results enable direct comparison between different forming lubricant types as well as provide valuable information to guide lubricant selection for aluminum sheet forming.

11:30 am – 12:00 pm

3834190: Comparison of Tribometer Reciprocating Performance Under Identical Conditions

Cole Frazier, Southwest Research Institute, San Antonio, TX

A number of different tribometers produced by different manufacturers are available to the industry as tools to understand friction and wear performance of lubricants or materials. While the basic principle of reciprocating testing is fundamentally the same, slight variations in how each tribometer achieves reciprocating conditions may vary tribometer to tribometer. In order to understand potential differences, data was collected on a Bruker UMT, SRV, TE77, and HFRR. Where needed, modifications were made such that all machines could test a 6mm ball and 10mm disk. Reciprocating frequency, temperature, applied load, and stroke length were fixed for all cases. In this presentation, major findings from the collected data will be presented.

Session 7H | 103C

Commercial Marketing Forum VII

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:30 am

3910686: Locus Performance Ingredients – Learning to Utilize Biobased Sophorolipids in Metal Cleaning and Degreasing at Neutral pH

Greg Smith, Locus Performance Ingredients, Richmond, VA

Metal cleaning is a critical function in metals market. Cleansing process and corrosion protection oils prior to coating is required. Legacy cleansing leans heavily on petrochemical based surfactants and solvents. Pressure on VOC's, Proposition 65 trace materials, and carbon footprint is driving the need to review biobased and environmentally friendly options. Technology in bio-based surfactants and solvents is rising to the challenge. Biosurfactants show efficacy in these applications, but the hurdle is to educate and teach formulators how to use new technology in formulations. Presentation will introduce Locus Performance Ingredients' Sophorolipids under our Amphi™ series of products. Formulas using LPI's Sophorolipids and co-surfactants will be reviewed with both tradition and biobased solvents. Claims data on cleaning compared to benchmarks will be presented including formulas, pictures, and quantitative grading of oil removal.

8:30 am – 9:00 am

3930934: Chevron Oronite – Demonstration of H2-ICE Capable Engine Oil

Dinesh Bansal, Chevron Oronite LLC, Richmond, CA

Hydrogen internal combustion engines (H2-ICEs) are being evaluated as a potential pathway to help lower carbon intensity in the transportation and power generation sectors. H2-ICEs offer several advantages to Original Equipment Manufacturers (OEMs); such as retaining the existing engine architecture and hardware, whilst achieving lower carbon emissions.In this presentation, we will demonstrate our efforts to help enable the energy transition by developing additive/lubricant solutions that can assist OEM efforts to deploy H2-ICEs and address the performance challenges they may introduce. Here we share some of the results of the fundamental bench-scale studies showing the effect of hydrogen on additive and lubricant formulations.The findings of our studies will help advance our efforts to offer a robust and reliable lubricant additive technology to OEMs and our customers for use in hydrogen internal combustion engines without increasing the maintenance complexity for the fleet owners.

9:00 am – 9:30 am

3909498: Nouryon – Nextgen Natura Derived Friction Modifiers

Alvaro Jose Ortiz, John Dixon, Nouryon, Houston, TX

Engine oils and transmission fluids will continue to trend to lower viscosity to capture fuel economy benefits. Modern hardware as well as tighter regulations are requiring formulators to use lower sulfur, phosphorus, and ash levels components to assure performance and durability. Nouryon has a more than 20-year track record in developing friction modifiers for the lubricants industry and it keeps innovating. This time, Nouryon will present its latest research on ashless organic friction modifiers focusing on solutions that bring additional benefits and properties as well as synergetic effects when interacting with other components to help its customers optimize the performance of their formulations.

9:30 am – 10:00 am

3909912: PCC-Chemax – Novel Antiwear and Extreme Pressure Additives – A Designed Performance

Denise Cooper, PCC Chemax, Inc, Piedmont, SC

Sustainable production, eco-friendly raw materials, high bio-content, low toxicity on par with excellent performance, stability, seal compatibility, low volatility are some of the key challenges facing manufacturers of modern industrial lubricants. Growing expectations of final users require new solutions and more flexible approach from not only formulators but also raw materials' producers such as PCC Group. This presentation will focus on the architecture of phosphorus-based products – EXOfos and Rokolub used as extreme pressure and antiwear additives. We will specifically discuss impact of molecular design on final products' characteristics. PCC Group has over 40 years of experience in production of additives for: MWF, industrial lubricants and synthetic base stocks. A dedicated R&D team can address and accommodate various requests for new products and offer technical support.

Synthesis and laboratory testing performed at PCC Se Poland.

10:00 am – 10:30 am – Break

Session 7I | 104A

Electric Vehicles VII

Session Chair: Hyeok Hahn, Chevron Lubricants, Richmond, CA

Session Vice Chair: TBD

8:00 am – 8:30 am

3833903: High-Speed Elastohydrodynamic Traction and Film Thickness in Electric Vehicle Transmissions

Alexander MacLaren, Hugh Spikes, Amir Kadiric, Imperial College London, London, United Kingdom

Elastohydrodynamic (EHD) lubrication films in Electric Vehicle (EV) gear tooth and roller bearing contacts frequently operate at high entrainment speeds, where thermal power and high-shear rheological effects lead to excursions from classical film thickness and traction predictions. Quantifying these and correcting classical models for application to high-speed reduction gearboxes with low-viscosity lubricants in EVs, is paramount in the optimization of both efficiency and reliability. In this study, a new test rig, the EHD-HS by PCS instruments, is used to measure film thickness and traction at entrainment speeds up to 20 m/s by optical interferometry in a ball-on-disc contact. Film thickness maps of the contact are also obtained using the Spacer Layer Imaging Method (SLIM). This talk explores key implications of high-speed EHD effects for EV drivetrain efficiency and surface damage, in the context of gear churning losses, for which reliable models at EV-speeds are not yet available.

8:30 am – 9:00 am

3834025: Optimizing Electric Vehicle Transmission Efficiency Using a Thermally Coupled Gearbox Lubrication Model

Joseph Shore, Amir Kadiric, Imperial College London, London, United Kingdom

We present a systematic study to evaluate the effects of lubricant properties and gearbox design on power losses in a typical EV transmission. The study uses an updated, thermally coupled lubrication model to predict gear mesh, gear churning and bearing losses in an EV transmission employed in a popular passenger EV. The model uses measured oil rheology as input allowing it to differentiate between nominally similar oils. A new empirical gear churning model and an updated bearing loss models are employed to account for high speeds encountered in EVs. Predictions are compared to measurements made on the said vehicle during real world driving as well as dynamometer tests. The relative significance of gear, bearing and churning losses under different vehicle operating conditions as well as WLTP cycle are identified and the potential impact of oil properties and gearbox design on these losses is illustrated.

9:00 am – 9:30 am

3825698: Study on the Discharge Behavior of EV Motor Bearings

Liang Guo, Thijs Nijdam, Henk Mol, Lieuwe de Vries, SKF BV, Houten, Netherlands

Electric current discharge in the motor bearings is becoming more of a concern with the move toward electric vehicles (EV), since it can damage bearing surfaces and potentially cause premature failures. A series of discharge tests were carried out utilizing a self-improved ball-on-disc instrument under elastohydrodynamic lubrication regimes to better understand the nature of electric discharge in EV motor bearings. It demonstrates that the current test equipment can duplicate the electric discharge that occurred in EV motor bearings by contrasting the damaged sample surfaces with the returning bearings. In particular, the presentation will cover the design of the test rig, the acquisition and extraction of the discharge signal, the analysis of the damage surface, the model that explains discharge damage, and potential mitigation measures.

9:30 am – 10:00 am

3807461: Numerical Investigation of the Influence of Pitting Size on Electrical Properties of Roller Bearings

Anatoly Zaiat, Karim Khaled Ibrahim, Marcel Neu, Eckhard Kirchner, Institute of Product Development and Machine Elements, Darmstadt, Germany; Florian Michael Becker-Dombrowsky, Technical University of Darmstadt, Darmstadt, Hesse, Germany

Accurate modeling of the capacitance of rolling element bearings is of increasing significance in recent years, e.g., in the context of bearing damage estimation in electric machines. The capacitance of the elastohydrodynamic contact represents a part of a multi-physical state, which is most influenced by the occurring fluid flow. The occurrence of surface irregularities greatly affect the fluid flow, changing the capacitance in response. As experiments on test rigs show, the occurrence and severity of surface irregularities can be detected in the measured capacitance, allowing a precise assessment of whether and when a bearing needs to be replaced, thus reducing machine downtime and increasing resource efficiency. Therefore, in this work, the influence of pittings on the electrical properties of a two-dimensional line contact is presented for the first time. Depth, width and size ratio of pitting/rolling element are varied and finally the results are compared with real surface damage.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3835060: Electric Vehicle Drive System Specialty Fluids

Anant Kolekar, Valvoline LLC, Lexington, KY

The recent growth in electric vehicle (EV) market has significantly impacted the automotive industry along with 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. Drive System Fluids (DSFs) target vital EV requirements to improve friction reduction, overall efficiency, electrical compatibility and insulation, and electric motor and drive system heat transfer. Tribological testing for EV DSFs are conducted to evaluate the performance and further understand the effect of chemical properties of these specialty lubricants. Different formulations 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 8.5°C).

11:00 am – 11:30 am

3848522: Vehicle Electrification Trends and Traction Inverter

Ayush Lal, Aptiv, Pickering, Ontario, Canada

The presentation will give the audience a background on vehicle electrification, its current scenario and trends in electrification. Later, it will also deep dive in discussion about traction inverter, which is one of the essential components on an electric vehicle as it converts DC current from the battery to AC to drive an electric motor. A portion of the presentation will be discussing about 800V SiC inverters and how cooling plays a critical role in thermal management of inverters. We will be discussing about key industry players in the current scenario and impact of electric vehicles on the environment, including CAFÉ (Corporate Average Fuel Economy) requirement of the US government.

Session 7J | 201A

Metalworking Fluids V

Session Chair: Nicole Clarkson, Barentz North America LLC, Lisle, IL

Session Vice Chair: Bridget Dubbert, Engineered Lubricants Company, Maryland Heights, MO

8:00 am – 8:30 am

3830552: Advances in Bio-Based Metalworking Fluids – Addressing Formulation Challenges by Balancing the Use of Additives

Lea Tekath, Michael Stapels, Kao Chemicals GmbH, Emmerich and Rhein, Germany

This presentation focuses on a systematic approach to enable development of a diverse range of bio-based oil metalworking fluids by balancing the use of different additives. The multifunctional additives identified increase formulator's options to include more sustainable and high-performing components to meet the latest formulation requirements and demonstrate the criticality of using the appropriate emulsifier and amino alcohol chemistry. Novel, eco-friendly and hazard-free metalworking fluids that incorporate bio-based oils are an attractive alternative to mineral oil. Bio-based oils are readily biodegradable, renewable, and have excellent lubricity. However, poor oxidative stability and compatibility with additives creates several formulating challenges. The benefits of the emulsifier and amino alcohol chemistry identified can be explained through structure-property relationships and can be used by formulators to develop metalworking fluids that are sustainable and high-performing.

8:30 am – 9:00 am

3811283: Application of High-Speed Tribology to Evaluate the Performance of Cutting Fluids on Ti-6Al-4V Under Machining Conditions

Jack Secker, Chris Taylor, University of Sheffield, Sheffield, United Kingdom; Edward Jones, Hangsterfer's Labs. Inc., Mantua, NJ

Manufacturers are resistant to changing metalworking fluid due to uncertainty of performance from ineffective testing options. These consist of full-scale production tests, which are resource intensive and overly specific, or traditional benchtop tribometers, which are unable to simultaneously recreate extreme cutting zone conditions. By simplifying tool-workpiece geometry whilst maintaining the high speed and force required to excite extreme pressure additives and generate high temperatures, the pin-on-lathe setup is able to better replicate the lubricant's environment. In this study, a pneumatic piston applies a TiN PVD coated carbide pin in a pin-on-flat type contact on lathe-mounted Ti-6Al-4V tubes. Cutting fluid performance is assessed based on the measurement of coefficient of friction, wear, subsurface damage and tool temperature across a range of speeds, pressures and fluid concentrations to determine the effects of lubricity and heat control compared with traditional tests.

9:00 am – 9:30 am

3833702: Enhancing Lubricity for Increased CGI Machining Speeds

Amelia Hadler, Johnnie Thomlison, Britt Minch, The Lubrizol Corporation, Wickliffe, OH; George Georgiou, GEO2 SQUARED Consulting, Windsor, Ontario, Canada

Compacted graphite iron (CGI) is a material with significant growth projections for use in heavy duty truck, automotive, rail, and marine engine applications due to its high strength and power density. However, the unique metallurgy of CGI makes it significantly less machinable than conventional irons which has negatively affected adoption within the industry. The metallurgical desulfurization of CGI as compared to the lubricating presence of sulfur in conventional irons requires machining speeds of 30% slower and significantly lowers tool life. A series of milling experiments were conducted on CGI using a variety of lubricity additives. These experiments demonstrated that top-performing additives give distinct advantages in CGI machining as measured by tool wear and production speed, indicating that the use of enhanced lubricity additives enables faster CGI machining.

9:30 am – 10:00 am

3808552: Next-Generation Antiwear for Metalworking Fluids

Lucas Luz, Solvay, Paulínia, São Paulo, Brazil

The new generation of machine tools, increasing usage of lighter alloys for weight reduction, and more regulations demanding better classification of chemicals are the drivers to develop new additives to enable fluid formulators to overcome some of today's and future most pressing challenges. Phosphorus technology still plays an important role when it comes to surface protection and although it is a very well-known technology there is still room for innovation. This presentation is going to introduce Phosphorus technologies under development and the relationship between their structures and performances.

10:00 am – 10:30 am – Break

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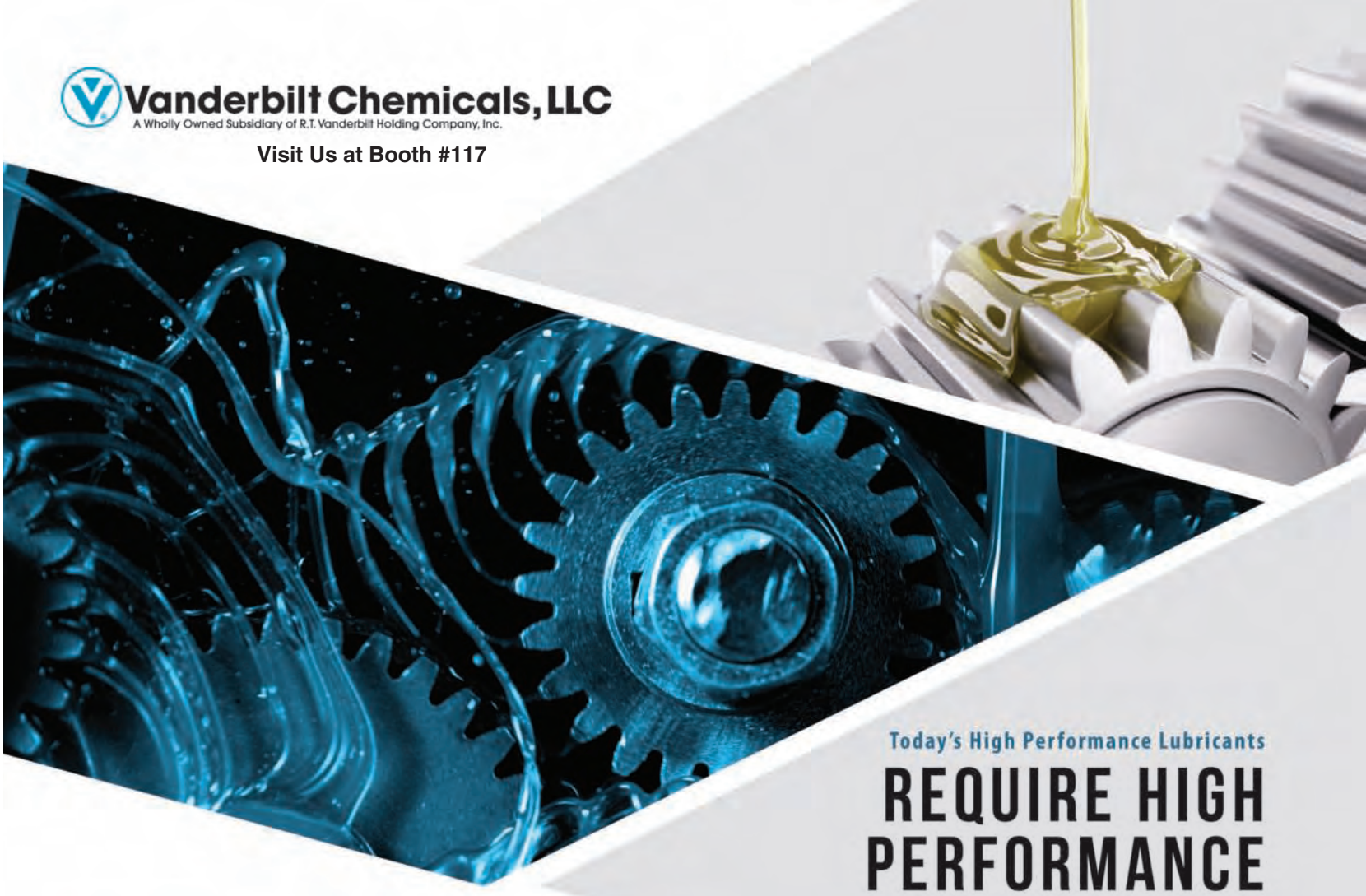

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Session 7K | 201B

Surface Engineering III

Session Chair: Uday Venkat Kiran Kommineni, University of North Dakota, Grand Forks, ND

Session Vice Chair: Pial Das, University of North Dakota, Grand Forks, ND

Session Starts at 9:00 am

9:00 am – 9:30 am

3804786: Making Surface Texture Meaningful: Case Studies in Surface Analysis for Tribological Applications

Mark Malburg, Digital Metrology Solutions, Columbus, IN

What is the roughness of North America? The answer depends on the context. Do we care about the heights of the mountains or do we care about having traction for our tires. In surface roughness measurement we have a similar problem: modern instruments can measure texture over such a range of shapes and details that the "correct" answer is much harder to define. In this talk we will discuss how advances in surface measurement and analysis, such as resolution, filtering, form removal, etc., both improve results and lead to complications. We introduce approaches to texture analysis that produce meaningful information from the millions of data points. Relevant tribological case studies in lubricant retention, gasket sealing, wear analysis, etc., will explain how to specify and standardize texture analysis to produce consistent, reliable measurement results.

9:30 am – 10:00 am

3812254: How Can We Avoid PET Bottle Pile-Ups During Conveying by Better Understanding Friction and Adhesion Phenomena?

Emmanouil Georgiou, Hellenic Air-Force Academy, Athens, Greece; Dirk Drees, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Lais Lopes, Christian Gerlach, Procter & Gamble Services Company S.A., Grimbergen, Belgium

A common problem in bottle manufacturing is the pile-up of bottles during conveying, due to static electrification caused by localized friction. To minimize such phenomena, a thin lubricant layer is applied onto the bottles. The absence of this layer increases the risk of localized sticking phenomena and pileups. In this work, an attempt is made to study the frictional behavior of commercially available PET bottles, with and without lubrication by using a high precision and light load technique. By analyzing the complete tribological pattern of the tangential force and not just averaged values, localized sticking events can be identified. In addition, by performing indentation-retraction measurements the electrostatic forces in a bottle-to-bottle contact can be measured. By combining light load friction and adhesion methods, a better understanding of PET sticking phenomena can be achieved which then can be translated in optimizing (minimizing) the amount of lubricant to be used.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3832761: Tribology: Adhesion, Friction, and Socioeconomy

Pankaj Tomar, IGDTUW/GGSIPU, New Delhi, Delhi, India

Tribology is a science of rubbing for materials and energy balances. The 21st Century is promoting sustainability for advancement of decent work and economic growth. The surface science, supramolecular chemistry of rubbing environment, and mechanical properties integrate TRIBO performance. The surfaces, interfaces, and interphases have been evolved by Nature for bionic functional materials in reducing energy consumptions. The mechanical loading, thermal loadings, biochemistry, and state variables altogether regulate interfacial supramolecular adhesion. The lowering surface energy and surface tension of hydrophobic interface creates a platform for functional non-stick functional coatings. The academic content may summarize socioeconomic retrospective role of tribology for advancement of academic innovation.

11:00 am – 11:30 am

3833336: Stick-Slip Friction: Mechanics, Mechanism, and Electroadhesion

Pankaj Tomar, IGDTUW/GGSIPU, New Delhi, Delhi, India

The stick-slip friction is ubiquitous in daily life for doing mechanical work in gait at slipping and sticking oscillatory contacts. The mechanical interlocking of skin texture on technological substate in a heterogeneous environment is a mechanism for providing stick-slip friction during human kinematics. Static friction of mechanically interlocked interphases is dependent on the real area of contact, asperities shear strength, temperature, and physiochemical indicators. The crushing of asperities peaks under applied or created loadings evolves sticking and slipping boundaries termed stick-slip friction. The stick-slip friction of the violin binds emotional intelligence for the achievement of human performance. The tactile friction, electroadhesion, and man-machine interface of Android mobile phones or smart digital devices have been noticed by author for researching for tribological performance.

Session 7L | 202A

Grease III

Session Chair: William Tuszynski, The Unami Group, Quakertown, PA

Session Vice Chair: Victoria Parker, Sasol Chemicals, Lake Charles, LA

Session Starts at 8:30 am

8:30 am – 9:00 am

3835074: Grease Patterns After Rolling Contact

Hao Qi, L.B. Foster, Burnaby, British Columbia, Canada

Film splitting is a research topic normally studied in the field of fluid mechanics. In an attempt to adopt the results of these studies to railroad grease applications, a series of laboratory experiments were conducted to study the efficiency of grease transfer and tackiness. During the tests, the grease products formed unique patterns after exposure to rolling shear stresses. These patterns align with previous research for so-called grease finger patterns. To further explore this phenomenon, a series of greases were tested using the same condition, including greases with various thickeners and oils. The results show that various greases exhibit distinct unique patters, which we attempted to categorize. These patterns are the result of very delicate physical and chemical interaction between oil and thickeners. It is proposed that this phenomenon and a

simple experimental set-up could be used as an additional tool to advanced techniques.

9:00 am – 9:30 am

3810505: Dissipative Particle Dynamics Simulations of Thickener Fiber Formation Process and Behavior Under Shear Flow

Honami Yanagisawa, Takashi Noda, NSK Ltd., Fujisawa-shi, Kanagawa, Japan; Tomoya Hasegawa, Hitoshi Washizu, University of Hyogo, Kobe-shi, Hyogo, Japan

Elucidating the relationship between microscopic structure and physical properties of lubricating greases is important for the development of high-performance greases. In this study, the formation process of thickener fibers and their behavior under shear flow were simulated by dissipative particle dynamics (DPD). As a result, it was confirmed that thickener fibers are oriented in the flow with dispersing due to shear, which is consistent with the conventional theory. Furthermore, quasi-SAXS simulations were performed for the fiber dispersion state, and it was found that the fiber behavior was calculated by DPD in qualitative agreement with the scattering change measured at SPring-8.

9:30 am – 10:00 am

3811289: Visualization of Grease Fluidity in a Ball Bearing Using Neutron Imaging Technology

Kazumi Sakai, Rui Ogata, Shuhei Yamada, Nobuharu Kimura, ENEOS Corporation, Yokohama, Japan; Yoshihiro Matsumoto, Comprehensive Research Organization for Science and Society, Tokai, Japan; Keisuke Kurita, Japan Atomic Energy Agency, Tokai, Japan

Neutron imaging technique was applied to visualize grease fluidity in bearings which determines the bearing torque property. Two types of lithium (Li) greases with different thickeners (Li complex and single Li soap) were used in this study. The Li complex grease was superior in lowering bearing torque related to energy-saving performance. After bearing rotations, neutron radiography and computed tomography measurements of the greases distributed in the bearings were performed. Adhesion of the Li complex grease to bearing balls was quite limited, and most of the grease stayed on cage surfaces between the balls; adhesion of single Li soap grease to bearing balls was remarkable. The neutron radiography with bearing rotations was also conducted to capture the moment of the grease flow. The observation with bearing rotations revealed that single Li soap grease flows gradually not from the beginning of bearing rotations. Based on these results, the lubrication mechanisms will be proposed.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3811764: Analyzing Wear and Additive Elements in Greases: XRF, RDE-OES or ICP-OES?

Christoph Rohbogner, Thomas Fischer, OELCHECK GmbH, Brannenburg, Germany

The elemental analysis in grease samples is standard in their analysis. However, there is no international standard available describing procedures. Thus, numerous often similar approaches are used in commercial laboratories. We have compared XRF, RDE-OES and ICP-OES analyses of different greases. In contrast to lubricant or fuel analysis, where international standards for OES analyses are published, no such procedures specifically for grease analyses using OES methods have been elaborated so far. Thus, differences in results between laboratories using different methods may be obtained. This is often revealed at round robin tests. We have compared results using XRF, RDE-OES and ICP-OES. The latter method using modern microwave assisted sample preparation.

11:00 am – 11:30 am

3813040: Effect of Oxidation on the Lubricating Performance of Greases

George S. Dodos, ELDON'S S.A., Athens, Greece

The evolution of oxidation products during oxidative deterioration may affect the lubricating properties of greases and thus the proper functioning of the lubricated machinery. In this study, a number of lubricating greases of various contemporary chemistries were employed and were subjected to accelerated oxidative deterioration under identical conditions. FTIR measurements were performed in order to detect relative changes that occur under these oxidizing conditions and to control the degree of oxidation per grease type. Subsequently, the oxidized samples were further analyzed and alterations in their tribological performance were assessed by carrying out determinations mainly under boundary lubrication in a four-ball tester. Differences in other fundamental parameters were also examined (e.g., dropping point, consistency) as part of a more comprehensive comparative assessment.

11:30 am – 12:00 pm

3831450: Film Thickness in Grease Lubricated Bearings: Effects of Grease Filling, Bearing Size and Grease Properties

Pramod Shetty, Robert Meijer, Jude Osara, University of Twente, Enschede, Netherlands; Rihard Pasaribu, Shell Project and Technology, Amsterdam, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

Film thickness is one of the important parameters that determine grease and bearing life. Understanding the parameters that govern the film thickness in bearings is vital to choose the operating conditions for the bearings. In this study, the film thickness is measured in a deep groove ball bearing using greases having different consistencies, viscosities, and thickeners, with different filling percentages, and in various-sized bearings. Results show that grease consistency has a significant influence on the replenishment of the contact; the low-consistency grease yielded higher film thickness than the high-consistency grease. The bearings of different sizes showed different film thicknesses, indicating that bearing geometry also influences lubricant replenishment in the contact. It is also observed that the initial quantity of grease in the bearing does not affect the film thickness in the early hours of bearing operation.

Session 7M | 202B

Wear II

Session Chair: Mathieu Renouf, Universite De Montpelllier, Montpellier, France

Session Vice Chair: TBD

8:00 am – 8:30 am

3814171: New Amine Phosphate Esters as Multifunctional Antiwear Additives

John Dixon, Ezio Amerio, Alina Filin, Rudy Venderbosch, Nouryon, Deventer, Netherlands

Industry trends and regulations demand a move towards ashless (or low SAPS) additives that ensure wear reduction while enabling the use of lower viscosity oils and improve energy efficiency. In this paper we report the development of a new class of amine phosphate esters as antiwear additives with good oil solubility and low phosphorous content. The lubrication properties are investigated by means of HFRR and the four-ball wear test, which showed excellent wear protection at lower treat rate compared to the industry standard zinc dialkyldithiophosphates (ZDDPs). We show that the selection of the amine moieties not only unlocks the ability to optimize independently wear and friction performances, but provide access to multifunctional AW additives – TBN, detergency, friction modifier. The combination of these attributes makes such products desirable candidates for a variety of lubricant applications including engine oils, hydraulic fluids, transmission oils, EV fluids and greases.

8:30 am – 9:00 am

3814203: RNT Wear Testing with Ultra-Low Viscosity Engine Oil on Full Bench Engine

Matthias Eggenstein, Shell Global Solutions, Hamburg, Germany; Peter Berlet, IAVF Antriebstechnik, Karlsruhe, Germany

Reducing greenhouse gas emissions is a key enabler for mitigating the impact of climate change. Increasing efficiency by lowering friction in available technologies is a quick step. Internal combustion engines (ICE) have significantly increased efficiency over the last decades. The crankcase lubricant plays an important role in reducing the ICE internal friction and improving efficiency. Lower viscosity oils result in thinner oil films reducing friction. However, there is concern very low viscosity may result in wear of engine components, as the oil film breaks, and contacts are operated in mixed or boundary lubrication regimes. Wear testing using the radio-nuclide-technology (RNT) provides precise real time measurement of wear in dedicated contacts. The wear behavior of different engine components has been investigated on a bench engine operated on a SAE 0W-12 engine oil. Various operational points and drive cycles were investigated to understand wear levels depending on operation mode.

9:00 am – 9:30 am

3819630: Wear of Aerospace Bearing Steels in Lubricated Reciprocating Tribotesting

Mathew Kirsch, Air Force Research Laboratory, Wright Patterson Air Force Base, OH

The aerospace bearing steels M50 (AMS 6491) and 52100 (AMS 6440) were subjected to reciprocating sliding wear tests both at room and elevated temperatures. Tests were conducted with fully formulated turbine engine oils containing phosphate based anti-wear additives as well as with an un-additized base stock. Additionally, M50 was subjected to multiple tempering conditions to investigate the dependence of wear on hardness under boundary lubrication. Post-test analysis of the surfaces was conducted to determine wear mechanisms and to examine the effect of oil additives on the wear rates of each material. An average wear area was calculated for each of the test conditions for comparison.

9:30 am – 10:00 am

3832512: The Use of the MTM Rig for Wear Testing

Matthew Smeeth, Clive Hamer, PCS Instruments, London, United Kingdom

A series of wear tests have been made using an MTM rig. The wear rate of any lubricated contact is dependent on a large number of factors, including, surface roughness, lubricant composition, environment, operating conditions, temperatures, etc. Since wear, in itself, is not an intrinsic property of a system, different wear tests can give very different results. Interpretation of different bench test results can be difficult and misleading conclusions can sometimes be drawn. Since the ability of a wear test to discriminate between lubricant formulations containing relatively small differences in additive concentrations is of paramount importance to any formulator, this information is detailed. A variety of typical anti wear additives have been used to study wear. Results show that the tests developed can produce measurable wear within a reasonable period of time. The repeatability and relative merits of the test methods employed are discussed.

10:00 am – 10:30 am – Break

10:30 am – 11:00 am

3832581: Effects of Trace Moisture Content on Tribo-Film Formation, Friction and Wear of CF-Filled PTFE in High-Purity Hydrogen

Qian Chen, Kyushu University, Fukuoka, Fukuoka, Japan

Carbon fiber (CF) filled polytetrafluoroethylene (PTFE) composites are widely used as piston ring materials for reciprocating hydrogen gas compressors. This study was aimed to investigate the effects of trace moisture content of hydrogen gas on tribological behavior of CF-filled PTFE composites. Sliding tests were carried out on pin-on-disk tribometer installed within an atmosphere-controlled chamber using a composite pin and a stainless-steel disk. The moisture contents of the hydrogen gas environment were controlled from 1ppm to 40 ppm while the contact pressure and sliding speed were set at 1MPa and 2m/s, respectively. The results showed that tribological behavior was significantly affected by trace moisture content. Specific wear rates of the composite pin tended to increase as the water content increased. Similarly, the average coefficient of friction increased while increasing the moisture content from 1 ppm to 20 ppm. However, it decreased with the further increase of water.

11:00 – 11:30 am

3812387: Enhanced Metal Corrosion of Long-Life Antifreeze Coolants

Hong Gao, Shell Global Solutions (US) Inc., Houston, TX

Corrosion protection is one of the critical performances of antifreeze coolants in transport and electric vehicles. The extended service life and compatibility with a wide range of metallic materials in the vehicles provide even more challenges on improving the corrosion performance of the liquid. This presentation highlighted the typical corrosion mechanisms in the cooling system and corresponding test methods. The enhanced corrosion protection was demonstrated with advanced long-life coolant technologies.

11:30 am – 12:00 pm

3813013: Local Contact Pressure Governs Mild Wear Mechanisms at Multi-Asperity Interfaces

Cyrian Leriche, ARCNL, DIemen, Noord-Holland, Netherlands

Wear causes surfaces to be irreversibly damaged; incurring significant economic cost. For single asperity contact between silicon-based materials –which are important in the MEMS industry- gradual attrition and fracture have been identified as the main wear mechanisms. To understand what mechanisms control the wear behavior of Si3N4-on-Si multi-asperity interfaces, we used the AFM topography difference method. We studied 'non-repeated' Si3N4-on-Si wear, imposing two different stroke lengths and found–over the full contact area – a transition in dominant wear regime as the local interfacial contact pressure decreased: from subsurface damage to atomic attrition. The wear per unit sliding distance induced by the short strokes is much higher than that sustained during long strokes, likely due to impact wear. Our method and results address a key challenge in tribology: to bridge fundamental insight into wear based on nanoscale studies to industrial applications.

Session 8C | 102A

Seals II

Session Chair: Lassad Amami, CETIM, Nantes, France

Session Vice Chair: Maximilian Engelfried, University of Stuttgart, Stuttgart, Germany

1:30 pm – 2:00 pm

3812371: Modelling of the Pumping Rate Behavior of Shaft Sealing Counterfaces

Maximilian Engelfried, Matthias Baumann, Frank Bauer, University of Stuttgart, Stuttgart, Germany

The term "lead" covers harmful structures on sealing counterfaces of rotary shaft seals. When the shaft is rotating, lead structures cause the shaft to pump oil through the sealing gap. Depending on the direction of rotation, leakage or insufficient lubrication of the sealing contact may occur. Therefore, the detection of such structures is an essential step in the quality assurance of shaft sealing counterfaces. This contribution presents correlation studies between the results of a new structured-based analysis method for macroscopic lead structures and the functional behavior of sealing counterfaces. The new approach describes the geometries of the measured structures on the shaft surface by means of statistically determined parameters. For the correlation studies, experimental pumping rate tests were carried out with sealing counterfaces with different lead characteristics.

2:00 pm – 2:30 pm

3833697: Experimental Study of a Reverse Pumping Spiral Groove Face Seal

Abdel-Salem Medjahed, Noel Brunetiere, Antoinette Blouin, Institut Pprime, Futuroscope Chasseneuil Cedex, France; Bálint Pap, Safran, Colombes, France

Reverse pumping face seals are designed with spiral grooves located at the low-pressure side (inner radius) pumping the fluid toward the high-pressure side to make the seal operating with no leakage. In addition, the grooves allow hydrodynamic pressure generation making the seal working in full film regime when the rotational speed is high enough. In this work, a face seal composed of grooved rotor sliding versus a transparent sapphire disk is experimentally studied. The location of the interface between the air pumped in the seal thanks to the groove and the pressurized liquid in the test rig is analyzed by an optical method. In addition, an infrared camera is used to measure the temperature of the sliding surfaces at different operating conditions. The impact of the air pumped in the sealing interface on the seal performance (leakage, friction and temperature) is studied.

2:30 pm – 3:00 pm

3829259: Tolerance Analyses on the Geometrical Parameters of Surface Textured Seals

Markus Brase, Matthias Wangenheim, Leibniz University of Hannover, Garbsen, Germany

Surface texturing is an effective method to control the friction level of dynamic seals. Texturing During Moulding (TDM) is an innovative method to manufacture surface textured seals in large quantities. Within this process, the negative of the desired surface texture is applied to the mould by laser ablation. The texture, defined by dimple diameter, distance and depth, is transferred from the mould to the seal during injection moulding or vulcanization. However, due to the laser and moulding process, geometric tolerances in both dimple dimensions and general seal dimensions occur. The objective of this study is the identification of the influence of those geometric tolerances on the friction level of surface textured seals. For this purpose, the contact pressures and dynamic frictional forces of piston seals in pneumatic cylinder are investigated both simulative and experimentally for a large variety of surface textures.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3806295: Experimental Determination of the Benefits of Textured Mechanical Seals on the Service Life of Systems

Lassad Amami, CETIM, Nantes, France

Seals are essential for the proper functioning of compressor, turbine, pumps, turbomachinery. The improvement of rotary machines performances depends especially on leak performance, durability, seal technology and its adaptation to dynamic solicitations. The objective of this study is to compare, experimentally, the performance of three new types of textured mechanical seals (triangle shape) with other smooth (non-textured) mechanical seals in terms of friction torque and leakage rate. The tests were carried out on a test bench dedicated to mechanical seals. The various test parameters, namely pressure, temperature, speed, leakage in the operating regimes were recorded and will be described in the article. The experimental results showed several sealing regimes (dry, mixed, hydrodynamic) of the mechanical seals depending on the depth of the textures. These results were also correlated with microscopic visualizations and metrological measurements.

4:00 pm – 4:30 pm

3846279: Measurement of Leakage and Visualization of Seal Surface of Dry Gas Seals with a Simple Inner Ring Groove

Masayuki Ochiai, Tokai University, Hiratsuka, Kanagawa, Japan

In this study, an inner peripheral ring groove was added to the generally used spiral groove for one-way rotation and the T-shaped groove for double-rotation, and air leakage was measured and compared. In addition, the flow of air flowing through the seal gap was confirmed by visualization experiments, and the effect of the inner ring groove on air leakage was verified experimentally.

8C

4:30 pm – 5:00 pm

3850067: Radial Shaft Sealing System Failure Mode – Shaft Lead

Adrian Heinl, Christian Wilbs, Daniel Froelich, Matthias Adler, Freudenberg FST GmbH, Weinheim, Baden-Württemberg, Germany

Lead structures on the shaft counter surface can cause premature failure of the radial shaft sealing system or to a reduced lifetime. Depending on the operation conditions and the lead characteristics the lead structures generate an axial pumping effect of the fluid. This leads either directly to leakage or poor lubrication conditions and therefore to an increased wear of the sealing lip. The shaft lead measurement is often performed according to the thread method defined in the RMA-OS-1-1. This method provides only little information about the lead characteristic and therefore the influence on the sealing system and especially the lead origin. This paper shows, how lead structures can be measured and quantitatively analyzed. Furthermore, the correlation between lead structures, leakage and the lead origin is explained. Those insights show hoe to avoid shaft lead and ensure a reliable sealing system performance.

5:00 pm – 5:30 pm

Seals Business Meeting

Session 8F | 103A

Biotribology II

Session Chair: Marc Masen, Imperial College of London, London, United Kingdom

Session Vice Chair: Brandon Krick, Florida State University, Tallahassee, FL

1:30 pm – 2:00 pm

3809745: Haptic Tribometer Characterizing the Dynamic Contact Between the Human Finger and the Automotive Touchscreen

Rexhina Shyti, Roberto Vargiolu, Hassan Zahouani, Laboratoire de Tribologie et Dynamique des Systèmes, Ecully, France; Pascale Nays, Renault Group, Paris, France

Although touchscreen technologies are ubiquitous, sole a few studies have focused their work on investigating the bio-tribology that lies under the interaction between the finger and the touchscreen. The device aims at assessing the dynamic contact between the fingertip and the touchscreen, it leads to a natural interaction between them to access the dynamic friction parameters such as the finger position, the velocity, and the dynamic contact area without constraining the finger's movement. The sensors paired with the haptic tribometer enable the measurement of the normal and tangential force, and the skin vibration by dint of an augmented finger developed within the laboratory. Coupling information garnered from the friction and vibration measurements with knowledge of the fingertip properties, as well as knowing the gesture employed, permit a better comprehension of tactile perception.

2:00 pm – 2:30 pm

3869334: Cellular Responses to Frictional Shear Stress

Angela Pitenis, Allison Chau, Kevin Ogbonna, Juan Manuel Uruena, University of California, Santa Barbara, Santa Barbara, CA

The ability of mucin networks to provide adequate lubrication in sliding contact with abiotic materials, such as contact lenses, can be significantly diminished to the point that patients report discomfort during use. Designing implant materials and surfaces that emulate the tribological behavior of natural mucin networks is paramount to improving patient comfort. In this work, we developed contact lens like hydrogel probes with controllable surface architectures to determine the extent to which frictional shear stresses could be mitigated by surface gel layers. We conducted tribological testing with hydrogel probes both with and without the surface gel layers against mucin-producing corneal epithelial cell monolayers. Experiments using hydrogel probes with surface gel layers were correlated with lower frictional shear stresses and less cell death than hydrogels without surface gel layers. These studies may assist in the design of more biocompatible implants, including contact lenses.

2:30 pm – 3:00 pm

3809804: Biotribological Characterization of the Physical Mechanisms at the Astringency Sensation Origin

Ianis Ammam, Roberto Vargiolu, Cyril Pailler-Mattei, Hassan Zahouani, Laboratoire de Tribologie et Dynamique des Systèmes – Ecole Centrale de Lyon, Lyon, France; Clément Nivet, Francis Canon, INRAE, Dijon, France

The astringency result from a loss of oral lubrification due to the aggregation of the mucosal pellicle by tannins. We recently proposed a new hypothesis on the molecular mechanism involved in this sensation, which is based on of the MUC1 protein. To evaluate this new hypothesis, we worked on an in vitro bilayer model simulating the oral mucosa composed of elastic hydrogel substrate (8kPa) and a cell layer recreating the oral epithelium by expressing MUC1 protein. This new in vitro model is very close to the oral mucosa in vivo from a physico-chemical perspectives: elasticity, wettability, roughness, protein adhesion. In addition, a micro-tribometer has been developed to perform in vitro friction tests and measured friction coefficient at the micrometric scale. We observed the role of saliva and the effect of astringent components on oral lubrication through the evolution of the in vitro friction coefficient on the mucosa model.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3810348: Biotribological Behavior of MXene-UHMWPE Composites

Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile; Klara Feile, Benedict Rothammer, Bartz Marcel, Wartzack Sandro, Friedrich-Alexander-University Erlangen-Nuremberg (FAU), Erlangen, Germany; Andreas Rosenkranz, Universidad de Chile, Santiago, Chile

MXenes are a relatively new class of 2D transition metal carbides, nitrides and carbonitrides receiving increasing attention in tribological applications due to their self-lubricating character. A prospective application of MXenes is their addition to UHMWPE with the overall purpose to improve the biotribological behavior of polymeric components of load-bearing implants. Within this study, Ti3C2Tx-UHMWPE composites with varying MXene content were biotribologically analyzed using pin-on-disk tribometer tests. Thereby, a friction reduction by up to 22% compared to pure UHMWPE was demonstrated. The determined wear rates of the disks considerably decreased by up to 43% due to the addition of MXenes. Furthermore, the composite-disks reduced the wear rates of the tested CoCr-pins by up to 19%. Both the reduction of friction and wear underline the great potential of MXenes as a reinforcement phase in UHMWPE to improve the biotribological behavior and service life of biomedical applications.


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8F

4:00 pm – 4:30 pm

3830758: Investigating the Tribological and Corrosion Behavior of Co-Cr Alloy as an Implant Material for Orthodontic Applications

Sudip Saha, Kommineni Uday Venkat Kiran, Sougata Roy, University of North Dakota, Grand Forks, ND

Effectiveness of wrought cobalt-chromium alloy as a dental implant was investigated through systematic tribological, immersion, and corrosion tests. Artificial saliva solution was prepared with varied pH levels. Effects of artificial saliva on Co-Cr samples were investigated by potentiodynamic polarization and continuous immersion tests. Tribological tests were conducted using a ball-on flat type reciprocating test rig against steel ball with different sliding velocities for both dry and saliva lubricated contact conditions. Oxide layer generation during dry contact conditions and formation of P and Ca enriched tribofilm originated from the artificial saliva played crucial role in tribological behavior of Co-Cr samples. In lubricated contacts, increased sliding velocity resulted in decreased friction coefficient which can be attributed to more homogeneous material transfer from ball to flat and artificial saliva-induced tribofilm formation on the Co-Cr flat wear track region.

4:30 pm – 5:00 pm

3830887: Photo-Responsive Hydrogel Lubricity

Allison Chau, Sophia Bailey, Kseniia Karnaukh, Javier Read de Alaniz, Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA

Stimuli-responsive hydrogels have a wide range of applications (e.g., drug deliver, soft robotics). Recently, light has been used to control swelling kinetics through the incorporation of spiropyran molecules into hydrogel networks, resulting in light-induced actuation and bending. However, the tribological properties of these photo-responsive hydrogels remain largely unknown. In this work, spiropyran-methacrylate was conjugated with acrylamide to form copolymerized hydrogel networks. In visible light, the photoswitch is hydrophobic in its spiro form. Once irradiated with UV light, isomerization to its hydrophilic merocyanine form occurs, inducing macroscopic hydrogel swelling. Using a microtribometer, we characterized the friction coefficient before and after irradiation. Based on these findings, we hypothesize that the deswelling-swelling transition is responsible for changes in the tribological properties of photo-responsive hydrogels, leading to decreases in friction coefficient.

5:00 pm – 5:30 pm

3853624: DECMA-1 Influence on the Mechanical and Tribological Properties of MDCK Monolayers

Emily Guo, Kyle Schulze, Auburn University, Auburn, AL; Steven Chisolm, Thomas Angelini, University of Florida, Gainesville, FL

Most of the research regarding e-cadherins (epithelial cadherin) and the use of DECMA-1, an e-cadherin antibody, are mainly for cancer research studies. By blocking e-cadherins, a protein responsible for cell-cell adhesion, the growth of tumors and cancerous cells can be hindered. However, these studies put a limit on the usage of DECMA-1 to confirming the presence of e-cadherins and hindering tumor growth. By affecting how much adhesion exists between cells, the properties of the cell monolayer itself should also change. By varying the dosage of DECMA-1 given to a monolayer of MDCK cells, the changes to the behavior of the cells were observed via confocal microscopy. Differences between the linear and rotational movement of the cell monolayer were observed.

Session 8G | 103B

Tribotesting IV

Session Chair: Juan Bosch Giner, The University of Akron, Akron, OH

Session Vice Chair: Amanendra Kushwaha, University of Nevada, Reno, Reno, NV

1:30 pm – 2:00 pm

3834410: Grinding Method Process Under Lab Conditions to Evaluate Railway Microstructural Response

Luis Wilches Peña, Valentina Castano, Miguel Vélez, Universidad EIA, Medellín, Antioquia, Colombia; Jaime Carvalho, Juan Sánchez, Hugo Santana, John Valencia, SENA, Centro de Tecnología de la Manufactura Avanzada, Medellín, Antioquia, Colombia; Alejandro Toro Betancur, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

Over the last years grinding processes have been used as a maintenance strategy to repair railways affected by Rolling Contact Fatigue. However, high plastic deformations and thermal impacts during grinding could be related to the beginning and evolution of microstructural changes called White Etching Layers (WELs). WELs have been related to surfacing damages responsible to railway significant life reductions. To study WELs, a grinding method process under lab conditions was designed. The method proposed is based on an adapted commercial polishing machine, where several load cells and thermocouples were assembled to railway sections fixed to the machine. Acquisition data from the sensors was made using signal conditioning, and ADC modulus circuits. An acquisition data card allows data storage and visualization in a HDMI screen. Information obtained from this method will be useful to understand the mechanisms responsible to WELs evolution.

2:00 pm – 2:30 pm

3834337: Cast Iron Chef: The Final Season

Alexander McGhee, University of Wisconsin-Madison, Madison, WI; Kylie Van Meter, Brandon Krick, Florida State University, Tallahassee, FL

The first known use of cast iron cookware was during the Han Dynasty in China, around 220 A.D, and ever since chefs have debated the best surface treatment. Surprisingly, this question has remained largely untouched by experimental tribologists, yet many of the current recommendations for cast iron seasoning claim certain oils give superior wear resistance. In this study, we utilize a high-temperature reciprocating tribometer with a stainless-steel counter surface to simulate cooking action. Tribological characterization of the cast iron pan as well as analysis of the morphology of surface and sliding interface give insight into the ideal seasoning conditions for cast iron cookware. Additionally, the surface properties such as hydrophobicity, wear resistance, and hardness will be compared to one another with consideration given to the polymer structure of the various oils.

2:30 pm – 3:00 pm

3835228: Effect of Gas Environment and Test Speed on Reciprocating Wear Testing for Compressor Packing Seal Materials

Jonathan Penaranda, Burak Bekisli, Tanil Ozkan, Dover Precision Components, Houston, TX

The tribological behaviors of dynamic polymer seals are influenced by the tribochemistry characteristics of the sliding contact, and these chemical characteristics are mainly influenced by the gas environment in which they operate. However, this variable is often not well understood, and the selection of wear-resistance polymer materials primarily

depends on field experience. An additional challenge when testing compressor packing seal materials is the sliding speed. Typical reciprocating compression operates at a linear speed between 2- 4 m/s, while most environmentally controlled reciprocating lab-scale wear tests operate between 0.005 and 0.2 m/s. In this paper, we will compare the wear performance of typical compressor seal materials on different sliding speed ranges and gas environments to discuss the main differences between the wear behavior observed for PTFE-based and PEEK-based compressor seal materials.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3892830: Tribological Behavior of Bearing Materials in Water-Based Lubricants

Juan Bosch Giner, Christopher DellaCorte, The University of Akron, Akron, OH

Despite having generally low viscosities, water-based lubricants (WBLs) present potential advantages compared to traditional oil-based lubricants. They can perform two tasks, cooling electric components and lubrication of rotating parts. Unfortunately, little information is available regarding their tribological behavior in steels and emerging ceramic bearing materials. This presentation describes an ongoing effort to characterize WBLs through rheological and tribological tests and compare them with its commercially available candidates and traditional lubricants.

Session 8I | 104A

Electric Vehicles and Engine and Drivetrain VIII

Session Chair: Andrew Velasquez, Southwest Research Institute, San Antonio, TX

Session Vice Chair: Kora Farokhzadeh, DSM Engineering Materials, San Jose, CA

1:30 pm – 2:00 pm

3847574: Ring-Liner Testing in a Hydrogen Environment

Peter Lee, Southwest Research Institute, San Antonio, TX

As the world moves towards net zero, Hydrogen is again being considered as an alternative to conventional petroleum-based fuels. There are many ideas, but little is known about the effect of Hydrogen in oil, or its effect on engine components. SwRI has adapted a reciprocating rig and built a dedicated explosion proof test cell in which to perform tribology experiments in a controlled Hydrogen environment. Pin on plate, and ring on liner components in engine oil were investigated. This work is in its infancy, but the test set-up and initial results will be presented.

2:00 pm – 2:30 pm

3903915: The Engine Oil Effect on Fuel Economy Improvement in Different Test Types

Kongsheng Yang, William Anderson, Kristi Engelman, Guoqing Cao, Afton Chemical Corporation, Richmond, VA

Climate change awareness greatly increased the desire to reduce CO_2 emissions. Modern engine manufacturers and lubricant manufacturers have demonstrated that CO_2 emission reduction can be achieved by increased fuel economy. There are multiple ways to measure engine oil fuel economy including motored engine and vehicle testing. Motored engine friction testing is a well-established methodology to demonstrate the effectiveness of lubricants to reduce the internal friction of an engine and provide fuel economy benefit. Likewise, fuel economy may be tested by vehicle chassis dyno test like the GM Oil Efficiency Evaluation (GMOEE). The GMOEE was introduced to the GM dexos™1 Gen 3 specification using a WLTC drive cycle after 500 miles aging. In this presentation, both engine oil component and fluid properties are able to improve fuel economy in both motored friction and vehicle fuel economy testing.

2:30 pm – 3:00 pm

3879003: Development and Testing of a Variable Hardness Piston Ring Coating for Improved Run-In

Peter Lee, Southwest Research Institute, San Antonio, TX; Lake Speed Jr., Total Seal Piston Ring, Concord, NC

Rings & liners must run-in before reaching optimum performance & oil control. A top softer run-in coating is better for removing asperities and gives optimum surfaces after which a lower harder durable coating is best. So, a dual coating is required. WC/C on CrN is available but not always successful due delamination problems. Therefore, engines are often operated with no piston ring coating or a single durable coating which is not optimum. Work by SwRI developed a durable low friction Ti-Si-C-N coating. In a full vehicle fuel economy savings of 0.82% were obtained. The Ti-Si-C-N coating is 'tuneable' during the deposition process giving a softer top layer. Being the same coating with different hardness applied in one process removes delamination concerns. Coatings were tested in a tribometer and liner surfaces analyzed (3D & SEM) to find the best coating. SwRI worked with Total Seal Piston Ring to install the variable hardness piston rings in a NASCAR engine to observe improved horsepower.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3867560: Electric Vehicle Fluid Interactions in AC and DC Environments

Andrew Velasquez, Carlos Sanchez, Peter Lee, Cole Frazier, Southwest Research Institute, San Antonio, TX

The tribology field has been established in determining performance of lubricants operating within internal combustion engines (ICE), with the backing of many standardized agencies. There is increasing demand for electric vehicles (EV) from government and civilian entities, and the lubricants market has been unable to effectively study how their fluids will perform in an electrified environment. This remains a key factor in EV performance, as studies have shown that lubricants function differently in the presence of electricity. Therefore, a standardized lubricant qualification method was modified to operate in an electrified environment with alternating (AC) and direct (DC) type currents. Three different EV fluids were exposed to similar operating conditions that would be seen in gearbox systems within EV's. To evaluate EV fluid performance, the friction and wear of the interacting standardized components were analyzed.

4:00 pm – 4:30 pm

3889385: High-Temperature Thermoplastics in Electric Drivetrain Bearings

Kora Farokhzadeh, Adnan Hasanovic, Geert Vanden Poel, John Papadopoulos, Trevor Spence, Matt Marnell, DSM Engineering Materials, San Jose, CA

High-temperature polyamides (PAs) play a key role in making e-mobility safer, lighter, and more sustainable and are widely used in various applications incl. high-voltage drivetrains. High-voltage and fast switching power electronics improve single-charge range and power density of electric drive units but increase the risk of electric discharge and premature failures in the bearings. Furthermore, compared to combustion engines, e-motors run transmission bearings at faster

speeds, exposing bearings to higher temperatures, and mechanical/thermal stresses. This talk focuses on glass- and carbon-fiber reinforced Stanyl PA46 EV bearing cages tailored for low friction, high wear resistance, dimensional stability, lightweight, high strength esp. at temperature (150-220°C), and creep resistance. Additionally, Stanyl PA46 grades are easy to mold and process with chemical resistance to lubricant/grease formulations. This enables manufacturers to maximize component reliability and lower production costs.

4:30 pm – 5:00 pm

3832947: How to Improve Engine Lifetime by Use of Premium Fuel

Nicole Doerr, Marcella Frauscher, Adam Agocs, Thomas Wopelka, Andjelka Ristic, AC2T research GmbH, Wiener Neustadt, Austria, Austria

To assess the influence of fuel quality on engine lifetime the wear performance of conventional fuel was compared to wear behavior of premium fuels containing elevated levels of FM. Engine bench tests were carried out with an artificially aged engine oil matching 25,000 km of operation. Wear formed during engine bench test was assessed by detection of wear particle concentration in the oil by ICP-OES and by radio isotope concentration method. Premium fuel showed significantly lower wear formation during engine bench tests. Oil aliquots sampled during engine bench tests revealed chemical changes during operation, measured by mass spectrometry. Transfer of FM from the fuel into the engine oil with proceeding engine operation time was revealed for premium fuels, leading to enhanced engine lifetime. This behavior was subsequently simulated in SRV® tribometer experiments, resulting in an efficient and economical laboratory method to support R&D.

5:00 pm – 5:30 pm

3832068: Novel Sustainable Low-Viscosity Synthetic Base Fluids for E-Mobility

Michael Liang, Ramesh Navaratnam, Patech Fine Chemicals, Dublin, OH

To meet the operational efficiencies of Hybrid (HEV) and Electric Vehicles (EV) technologies the transmission e-fluid requirement has moved toward low-viscosity fluids. Transmission e-fluids used in HEV, and EV are also in direct contact with different electrical components of the motor like battery, transmission gear, and integrated electric motors. This introduces new challenges of requiring excellent electrical and thermal properties of e-fluids to prevent the risk of electric short circuit and overheating. However, conventional low-viscosity base fluids have poor lubricity performance that reduce reliability and performance. In this study, we will demonstrate the benefits of synthetic esters to provide better heat transfer and di-electric properties than other base stock. In understanding these mechanisms, we were able to develop esters specifically for higher heat conductivity, low viscosity with excellent lubricity, and eco-friendly to achieve the goal of sustainability as well.

5:30 pm – 6:00 pm

3834981: High Performance Synthetic Lubricants Designed for High-Speed e-Mobility Application

Philip Ma, BASF, Tarrytown, NY

Automotive industry is moving rapidly toward electric vehicles. Off the shelf lubricant products for conventional vehicles are not optimized for the unique demands for e-fluids application, such as energy efficiency, electric conductivity, copper protection, aeration, extended gear/bearing protection etc. This presentation will highlight high-performance PAO-based formulations designed for high-speed e-fluid applications.

Session 8L | 202A

Grease IV

Session Chair: Lu Fang, University of Pennsylvania, Philadelphia, PA

Session Vice Chair: William Tuszynski, The Unami Group, Quakertown, PA

1:30 pm – 2:00 pm

3832174: Quantum-Leap Grease Formulation Through Preform Chemistry

Noura Smaili Iderkou, Novitas Chem Solutions, Tomball, TX

For decades grease is made via in-situ manufacturing whereby the thickening takes place in the presence of base oil at elevated temperatures that is energy intensive and is difficult to achieve grease consistency in the so-called soap kettle. We have found using pre-form thickeners grease making can be made much simplified/easier and consistent. This pre-form concept is built on the fact that the thickener is already formed and sized for optimal thickening in either powder or extrudate forms. The same concept can be extended to additives and components in which grease performance can be achieved without compromising the integrity of the grease with no softening or oil separation. This paper shall present a novel grease formulation entirely based on preform chemistry that can be used to achieve high load and demanding applications.

2:00 pm – 2:30 pm

3834150: Best Practices for Making Urea Grease from a Powdered Thickener

Lauren Huffman, Dow Chemical, Midland, MI

This talk with teach the best practices and challenges of making a urea-based grease from a powdered thickener.

2:30 pm – 3:00 pm

3811237: Influence of Grease Thickener Types on the Film Formation

Tomoki Kamihata, Kazumi Sakai, ENEOS Corporation, Yokohama, Japan

The film thickness of greases has a significant impact on bearing properties, such as the bearing torque. Therefore, for a detailed discussion of the lubrication mechanism, it is important to improve the accuracy of film thickness measurements. However, in the case of conventional equipment, the measurement methods of the thin film formed at lower speed range are technically limited. In this study, the film thicknesses of two types of urea greases, alicyclic and aliphatic ureas, were observed by using a high-accuracy film thickness observation equipment using optical interferometry technique. Alicyclic urea grease formed much thicker film compared to aliphatic one at lower speed range. This result suggests that the increase of the film thickness is attributed to the thickener structure of ureas. It seems that this phenomenon is caused by the intervention of large thickener particles and/or the thickener condensation in/around Hertzian contact areas, as successfully captured images.

3:00 pm – 3:30 pm – Break

3:30 pm – 4:00 pm

3813022: DIN 51830-2 – Evolution of an Advanced Method for Characterization of Thermo-Oxidative Grease Failure

Markus Matzke, Robert Bosch GmbH, Renningen, Germany; Olav Höger, Shell Global Solutions Germany GmbH, Hamburg, Germany; Thomas Litters, FUCHS Lubricants Germany GmbH, Mannheim, Germany; Jürgen Fischer, DIN Technical Committee on Mineral Oil and Fuel Standardization, Hamburg, Germany

Thermo-oxidation is a dominant degradation mechanism of greases in automotive applications. To ensure adequate lubrication across the complete vehicle life, the resistance to degradation must be quantified by appropriate test methods. Existing thermo-oxidative test methods for greases like DIN 51808 or ASTM D 8206 do not include contact with catalytic materials like brass or steel and the evaluation criteria do not indicate antioxidant depletion as initiation of structural grease failure. Therefore, the existing RSSOT method was enhanced by integrating catalytic contact materials steel and brass and application of a new evaluation criterion for grease failure. Additionally, it enables the calculation of the Arrhenius activation energy. This presentation summarizes the evolution of this method at the German Institute for Standardization (DIN) from the initial concept, a working group study to determine activation energies, an official round robin test to the final DIN standard.

4:00 pm – 4:30 pm

3829730: Oxidation and Grease Life in Rolling Bearings

Piet Lugt, SKF Research and Technology Development, Houten, Netherlands; Mikael Holgerson, Fredrik Reinholdsson, SKF, Gothenburg, Sweden

In this presentation the lubrication mechanism is described of lithium grease lubricated ball bearings in the bleed phase. Oxidation plays an important role and therefore grease life "in air" and grease life "in nitrogen" is studied in real bearings. It is shown that grease life is strongly dominated by oxidation but that this is by far not deterministic. Oxidation starts up at a certain time, the induction time, which is the point at which the antioxidants have been consumed. This induction time is a function of the bearing operational conditions and the oxygen concentration. Oxidation leads to loss of base oil and loss of lubricity, partly repaired by replenishment and oil release from the grease reservoirs (bleed).

Session 8M | 202B

Wear III

Session Chair: Yan Zhou, Quaker Houghton, Conshohocken, PA

Session Vice Chair: Mathieu Renouf, Universite De Montpelllier, Montpellier, France

1:30 pm – 2:00 pm

3833731: An Investigation into the Tribological Performance of Wear Resistant PVD Coatings Atop Various Tool Steels Used in Injection Moulding Applications

Roshan Lal, University of Birmingham, Wolverhampton, United Kingdom

Wear is a recurring issue in injection moulding applications where abrasive formulations, high temperature and high pressures are employed. Multiple wear mechanisms can damage a single tooling part during production, so protective coatings are often applied by Physical Vapor Deposition (PVD). A variety of coatings (TiAlN, AlCrN, Diamond-Like-Carbon (DLC), CrN etc.), coated atop two tool steel grades have undergone rigorous laboratory testing to evaluate their tribological performance. Nanoindentation, macro-scratch testing, interferometry, atomic force microscopy and a bespoke particle-entraining tribometer at elevated temperatures are among the plethora of techniques implemented to reveal the optimal substrate-coating combination. Wear resistance is shown as a function of both the coating and substrate properties.

2:00 pm – 2:30 pm

3833738: Friction and Wear Characteristics of Pitch & Poly-acrylonitrile-Based Carbon-Carbon Composites in Air and Nitrogen Environment Under Aircraft Taxi Conditions

Akshat Sharma, Farshid Sadeghi, Purdue University, West Lafayette, IN

In this investigation, a disc brake test rig was designed and developed to evaluate the friction and wear characteristics of pitch and poly-acrylonitrile based carbon-carbon composites in air and nitrogen environment. Friction results from drag tests were validated with existing literature. Additionally, controlled tests at specific temperatures and energy flux were performed using an external thermal chamber (temperatures up to 5500C) to quantify the wear coefficients. It was found that temperature of the disc, humidity of surrounding environment, supplied energy flux as well as the type of composite play a critical role in determining whether disc brakes operate in normal wear or dusting wear regime. Furthermore, optical and scanning electron microscopy were conducted to analyze wear mechanisms. Matrix and interface cracking along with fiber breakage were observed from tests in air environment, whereas in nitrogen environment, particulate and layered debris played a prominent role.

2:30 pm – 3:00 pm

3833918: Wear Characteristics of ZDDP Tribofilm

Armand Tamouafo Fome, Leibniz University Hannover, Hanover, Germany

Zinc dialkyldithiophosphates (ZDDPs) are the most commonly used additives in engine lubricants when it comes to minimizing wear. This is achieved by forming a protective tribofilm on the surface of the raceway. Thus, the effectiveness of ZDDP depends on the balance between tribofilm formation and wear rate. In this study, a simple test procedure was set up to investigate the formation and wear of a zddp tribofilm. The focus of this study was on the transition from mild to severe wear. To this end, wear tests were conducted on a two-disc machine. Starting from a mild wear condition with ideal conditions for the formation of a ZDDP tribofilm, the test parameters were gradually changed until the severe wear state was reached. In this condition, the tribofilm formation rate could not keep up with the wear rate. Consequently, the substrate wear was observed.

3:00 pm – 3:30 pm – Break

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 people 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.

Participants Index 2023

Includes technical program authors, Commercial Marketing Forum (CMF) presenters, Early Career Research (ECRP) and Student Poster (SP) authors.

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