Passion for Solutions™

PEOPLE ▲ CHEMISTRY ▲ SOLUTIONS

INDUSTRIAL LUBRICANT ADDITIVES

- Exclusive, customized solutions
- Fully-equipped laboratories worldwide
- Local R&D capabilities
- In-depth product knowledge, advanced technology, and premium product offerings
- Integrated global supply chain

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See us in booth 7 at STLE 2011
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The 2011 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. E-mail: information@stle.org. Web: www.stle.org.
STLE is a not-for-profit professional society founded in 1944 to advance the science of tribology and best practices in lubrication engineering.
Welcome to Atlanta and five days of world-class education, training and networking

Dear Members, Friends and Guests,

Welcome to STLE’s 66th Annual Meeting & Exhibition!

Two key STLE committees, the Annual Meeting Program Committee and the Education Committee, have assembled a challenging technical program featuring nearly 400 paper presentations. You can look forward to an outstanding week of professional development here in Atlanta.

In addition to the technical sessions, the meeting’s program includes 10 one-day education courses and many chances to network with and learn from your peers. I also encourage you to take time out of your schedule to visit companies displaying in the trade show. This is an opportunity to get an early look at the newest technologies the lubricants industry has to offer.

Remember, also, to take advantage of the social events, including the Welcoming Party Monday at 6:30 p.m. and the President’s Luncheon Tuesday at noon. You’ll reconnect with the entire STLE community and have a chance to recognize the many volunteers who generously donated their services in the last 12 months to create new programs for all of us involved in the science of tribology and best practices in lubrication engineering.

By popular demand, we’ve brought back The STLE Lounge inside the trade show. The lounge is a great place to relax and conduct business with personnel from exhibiting companies. The exhibit area also is where you’ll see nearly 40 student posters on display – please come recognize our industry’s future leaders.

I also urge you to take advantage of the Commercial Marketing Forum, where the lubricant industry’s most innovative companies discuss their latest products and services. The forum sessions are listed with the technical tracks in this program guide.

STLE’s 2011 Annual Meeting & Exhibition is a singular opportunity to discover technical concepts and make personal contacts that will help you better serve your employer and customers and advance your career. In just five days you’ll have access to a wealth of technical information that would take you months to find on your own.

Please say hello if you see me in the halls or meeting rooms. I’m looking forward to joining you on this journey.

Peter Drechsler, The Timken Co.
Expanding energy efficiency
Evonik Oil Additives – customized solutions for tomorrow’s formulations

From wind turbines to automobiles and beyond, Evonik Oil Additives are changing expectations for energy efficiency. Our innovative technology combined with custom formulating expertise is maximizing efficiency around the world. Learn more at www.rohmax.com.

Evonik. Power to create.
Daily Schedule at a Glance

All room numbers refer to Hilton Atlanta.

Sunday, May 15, 2011

Registration
7 am – 6 pm – 2nd Floor Foyer

Speakers Breakfast
7 – 7:45 am – Salon A-C

Education Courses (8 am – 5 pm)
Basic Lubrication 101 – 302
Bio Fuels and Lubes – 305
Condition Monitoring – 306
Hydraulics – 303
Synthetic Lubricants 203 – 304

Education Courses (1:30 – 5 pm)
Nanotribology Special Session – 309/310

Local Section Leader Workshop (5 – 6:30 pm)
“Committee Meetings that Work,” by Drs. Jean & Ed Becker – 309/310

Monday, May 16, 2011

Registration
7 am – 6 pm – 2nd Floor Foyer

Speakers Breakfast
7 – 7:45 am – Salon A-C

Technical Sessions (8 – 10 am)
1A Rolling Element Bearings I: Erwin V. Zaretsky Symposium – 202
1B Nanotribology I: Nanomaterials and Applications I – 203
1C Lubrication Fundamentals I – 204
1D Biotribology I: Skin Tribology, Modeling – 205
1E Wear I – 206
1F Fluid Film Bearings I – 209
1H Metalworking I: Fluid Health, Safety & Longevity Session 1 – 211
1K Condition Monitoring I – 214

Commerical Marketing Forum I – Salon D/E

Keynote Address (10:30 am – Noon)
“Biological Principles and Biomimetics of Tribologically-Active Materials,” presented by Stanislav N. Gorb – Grand Ballroom C/D

Lunch
Noon – 1:30 pm (on your own)

Exhibits and Student Posters
Noon – 5 pm – Exhibit Hall

Tuesday, May 17, 2011

Speakers Breakfast
7 am – 7:45 am – Salon A-C

Registration
6:30 am – 5 pm – 2nd Floor Foyer

Technical Sessions (8 am – Noon)
3A Rolling Element Bearings III – 202
3B Nanotribology III: Nanomechanics – 203
3C Lubrication Fundamentals III – 204
3D Ceramics/Composites I – 205
3E Wear/Seals Panel I – 206
3F Fluid Film Bearings III – 209
3G Biotribology II: Orthopaedic Tribology – 210
3H Metalworking III: Testing & Modeling Fluid/Additive Performance – 211
3I Engine & Drivetrain II – 212
3J Practical Lubrication I – 213
3K Condition Monitoring III – 214

Commerical Marketing Forum III – Salon D/E

President’s Luncheon/Business Meeting
Noon – 2 pm – Grand Ballroom C/D
Daily Schedule at a Glance

All room numbers refer to Hilton Atlanta.

Tuesday, May 17, 2011/continued

Technical Sessions (2 – 6 pm)
4B Nanotribology IV: Nanolubricants I – 203
4C Lubrication Fundamentals IV – 204
4D Material Tribology I – 205
4F Fluid Film Bearings IV – 209
4G Biotribology III: Ocular Tribology – 210
4H Metalworking IV
Workpiece & Tool Effects on Metalworking – 211
4I Engine & Drivetrain III – 212
4J Practical Lubrication II – 213
Commercial Marketing Forum IV – Salon D/E

Wednesday, May 18, 2011

Registration
6:30 am – 5:00 pm – 2nd Floor Foyer
Speakers Breakfast
7 – 7:45 am – Salon A-C
Exhibits and Student Posters
9:30 am – Noon – Exhibit Hall
Education Courses (8 am – 5 pm)
Advanced Lubrication 301 – 302
Basic Lubrication 102 – 305
Metalworking – 309/310
NLGI Grease Course 101 – 303
Synthetic Lubricants 204 – 301
Technical Sessions (8 am – Noon)
5B Nanotribology V: Nanolubricants II – 203
5C Lubrication Fundamentals V – 204
5D Material Tribology II – 205
5E Seals I – 206
5F Tribotesting I – 207
5G Fluid Film Bearings V – 209
5H Gears I – 210
5I Contact Mechanics – Materials Tribology and Nanotribology Joint Session I – 203
5J Grease I – 204
5K Seals III – 206
5L Surface Engineering I – 211
5M Environmentally Friendly Fluids I: EFF Applications – 212
5N Non-Ferrous Metals I: Biobased Lubricants Options for Industry – 213
5O Power Generation I – 214
Commercial Marketing Forum V – Salon D/E

Thursday, May 19, 2011

Speakers Breakfast
7 – 7:45 am – Salon A-C
Registration
7:30 am – 2 pm – 2nd Floor Foyer
Technical Sessions (8 am – Noon)
7A Wind Energy I – 202
7B Contact Mechanics – Materials Tribology and Nanotribology Joint Session I – 203
7C Grease I – 204
7D Tribotesting III – 205
7E Seals III – 206
7F Surface Engineering III – 211
7G Environmentally Friendly Fluids III: Base Oils for EFF – 212
Technical Sessions (1 – 5:30 pm)
8A Wind Energy III – 202
8B Contact Mechanics – Materials Tribology and Nanotribology Joint Session II – 203
8C Grease II – 204
8D Seals IV – 206
8E Additive Studies in EFF – 212
8F Environmentally Friendly Fluids IV
Additive Studies in EFF – 212
Beverage Breaks are scheduled at 10 am and 3 pm daily.
This planning tool is brought to you by Evonik’s energy efficient lubricant experts.

To use this planner: Review all the events in this guide, particularly the technical sessions on pages 38-142 and the errata in your registration bag. Indicate each event and location on the grid. You will have your own personal itinerary indicating where you should be during every minute of STLE’s 2011 Annual Meeting.

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<th>Time</th>
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Personal Itinerary Planner for: ______________________________________
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This planning tool is brought to you by Evonik’s energy efficient lubricant experts.

To use this planner: Review all the events in this guide, particularly the technical sessions on pages 38-142 and the errata in your registration bag. Indicate each event and location on the grid. You will have your own personal itinerary indicating where you should be during every minute of STLE’s 2011 Annual Meeting.

Thursday, May 19

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Hilton Atlanta

Meeting Room Layout – Second Floor
Hilton Atlanta

Meeting Room Layout – Third Floor
Hilton Atlanta

Meeting Room Layout – Fourth Floor
General Information and Policies

Exhibit Hours:

- **Monday:** Noon – 5 pm
- **Tuesday:** 9:30 am – Noon & 2 – 5:30 pm
- **Wednesday:** 9:30 am – Noon

Policies:

**Annual Meeting and Education Course Policies**
- All attendees must register.
- A badge is required for admittance to any session or education course.
- Annual meeting registration includes admittance to the trade show.
- Education course registration includes admittance to the selected education course or courses, all technical sessions and admittance to the trade show.
- Handouts are not permitted in any technical session. Handouts will be given to education course attendees.

**Recording Policy**

Taping, either audio or video, IS NOT permitted in any of the annual meeting technical sessions. Audiotaping 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 be taking photographs of technical sessions, education courses, social events and the trade show on Tuesday, May 17. These images will be used in print materials promoting STLE’s 2012 Annual Meeting & Exhibition in St. Louis. If you do not want your photo to appear in these materials, please step out of the picture fame or advise the photographer after your photo is taken.

**No Smoking Policy**

Smoking is not permitted in the technical sessions, courses, exhibits, registration area or any other areas of the facility involved with the STLE meeting.

**Cellular Telephones**

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

**Registration Information**

Attendees may register beginning on Saturday, May 14, from 3 – 6 pm at the STLE Registration Desk at the 2nd floor foyer in the Hilton Atlanta. The STLE registration desk is open daily thereafter through Thursday beginning at 7 am.

Registration for the annual meeting entitles you to attend the technical sessions, Welcoming Party on Monday evening, the trade show Monday through Wednesday, President’s Luncheon on Tuesday and all other officially sanctioned events.

Registration for an educational course entitles you to attend the course, any of the technical sessions, Welcoming Party on Monday evening, the trade show Monday through Wednesday, President’s Luncheon on Tuesday and all other sponsored events. It is not necessary to register for the annual meeting if you are already registered for a course with the exception of the Basic Grease course co-sponsored with NLGI. The Basic Grease course requires a separate AM registration.

Tickets are required for the President’s Luncheon. Annual meeting and education course registrations include a ticket to the President’s Luncheon. Additional tickets for the luncheon may be purchased at the registration desk for $50 each.

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

**Certification Exams**

**Thursday, May 19**
8:30 am – 12:30 pm – Rooms 406-407
The Certified Lubrication Specialist, Oil Monitoring Analysis Level 1, Oil Monitoring Analysis Level II and Certified Metalworking Fluids Specialist exams are given. Onsite registration for the exams is available at the STLE Registration Desk.

The exams take approximately three hours to complete.

**Fees:**
- **First time taking exam:** $320 Member, $430 Non-member
- **Re-take:** $160 Member, $215 Non-member

**Future STLE Meeting Dates**

**2011 International Joint Tribology Conference**
October 24-26, 2011
Marriott Los Angeles Downtown
Los Angeles, California

**2012 STLE Annual Meeting & Exhibition**
May 6-10, 2012
St. Louis, Missouri

**2013 STLE Annual Meeting & Exhibition**
May 5-9, 2013
Detroit, Michigan

**2014 STLE Annual Meeting & Exhibition**
May 18-22, 2014
Orlando, Florida

www.stle.org
COOKOUT AND GOLF OUTING
SUNDAY, MAY 15
11:30 am (cookout, noon tee times)
Bobby Jones Golf Course, 384 Woodward Way, Atlanta, Ga., 30305, 404-355-1009.
$64 per player includes greens and cart fees, sleeve of balls, glove and burger cookout.
Bus transportation provided from Hilton
Join us to play in the footsteps of Bobby Jones at this historic course located in the prestigious Buckhead section of Atlanta only 12 minutes by car from the Hilton Atlanta hotel. Enjoy this very playable course lined with live oaks, meandering creeks and the Atlanta skyline visible from many holes.

WELCOMING PARTY
MONDAY, MAY 16
6:30 – 8 pm – Grand Ballroom C/D
Join your colleagues for light fare, entertainment and networking with hundreds of your industry peers. A great place to meet before embarking on your dinner plans, the Welcoming Party is a “can’t miss” annual meeting tradition.

PRESIDENTS AWARDS LUNCHEON AND STLE 64TH ANNUAL BUSINESS MEETING
TUESDAY, MAY 17
Noon – 2 pm – Grand Ballroom C/D
Salute 2010 STLE Award Winners, 2010-2011 President Peter Drechsler and 2011-2012 President Michael Dugger while you enjoy a full lunch and participate in the business of STLE. The Presidents Luncheon is Tuesday, May 17, starting promptly at noon in Grand Ballroom C/D. Tickets to the luncheon are included with annual meeting or course registration. Additional tickets may be purchased for $50 per person at the STLE Registration Desk.

SPEAKERS BREAKFAST AND BRIEFING
MONDAY – THURSDAY
7 – 7:45 am – Rooms 406 & 407
Speakers and course instructors are invited to meet with the Session Chairs, Paper Solicitation Chairs and Session Monitors, Course Chairs, Course Vice Chairs and Course Monitors for a continental breakfast on the day of your presentation. This is an opportune time to review the session schedule and note any last-minute changes.
STLE’s 2011 Annual Meeting & Exhibition features 10 one-day courses, including one entirely new course on Biofuels and Lubes. STLE also is co-hosting a Basic Grease Course with NLGI). Unlike the rest of the education courses, this special course has a separate, independent tuition that does not include annual meeting registration.

Sunday, May 15

**BASIC LUBRICATION 101**
8 am – 5 pm • Room 302

- **Base Oil Fundamentals**, Jim Arner, Chevron
- **Additives**, Chris Schmid, Lubrizol
- **Lubrication Fundamentals**, Dan Holdemeyer & John Sewall, Chevron
- **Fundamentals of Hydraulics**, Tom Blansett, Eaton Hydraulics
- **Lubricant Testing Methods**, Ray Thiebault, LTC
- **Synthetics**, Ken Hope, Chevron/Phillips

**INTRODUCTION TO BIOFUELS AND LUBES**
8 am – 5 pm • Room 305

- **Introduction to Biofuels and Lubes**, Joe Perez, Penn State University
- **Chemistry 101: Petroleum and Biofuels and BioLubricants**, Joe Perez, Penn State University
- **Biodegradation, Regulations and Standards**, Neil Canter, Chemical Solutions
- **General Performance Requirements of Lubricants**, Joe Perez, Penn State University
- **Overview of Progress in Major Markets: Engine Oils, Hydraulic Fluids, Industrial Oils, & Greases**, Lou Honary, University of Northern Iowa
- **Growth of Niche Markets in the U.S.**, Mark Miller, Terrosolve Technologies
- **Biolubricant Developments and Markets in the European Market**, Joe Asaduasakas, University of Vilnius, Lithuania
- **USDA Biolubricant Programs**, Girma Biresaw, USDA, ARS, NCAUR, Peoria, IL
- **Biofuels and Other Alternative Transportation Fuels**, Joe Perez, Penn State University
- **Automotive Markets and OEM Concerns**, Jill “JJ” Cummins, General Motors
- **Biolubricants Review Session**, Neil Canter, Chemical Solutions
- **Biofuels Review Session**, Joe Perez, Penn State University

**CONDITION MONITORING 150**
8 am – 5 pm • Room 306

- **Why Condition Monitoring?**, Jack Poley, Condition Monitoring International
- **Basics of a CBM Program**, Evan Zabawski, Fluid Life
- **Oil Analysis Tests and Data Evaluation**, Jack Poley, Condition Monitoring International (CMI)
- **Failure Modes and Data Integration**, Allison Toms, GasTops

**HYDRAULICS**
8 am – 5 pm • Room 303

- **Course Introduction and Overview**, John Sherman, BASF
- **Basic Hydraulics**, Tom Blansett, Eaton
- **Functions and Requirements of Hydraulic Fluids**, John Sherman, BASF
- **Viscosity and Viscosity Impact on Fuel Efficiency**, Doug Placek, Evonik Rohmax
- **Hydraulic Fluid Composition – Base Stocks**, Paula Vettel, Amyris
- **Hydraulic Fluid Composition – Additives**, Betsy Burke, Lubrizol
- **Hydraulic Fluid Test Standards**, Patty Cusatis, BASF
- **Specialized Hydraulic Fluids**, John Sherman, BASF
- **Commercial Hydraulic Fluid Specifications**, Paul Michael, Milwaukee School of Engineering
- **Current Trends in Hydraulics and Hydraulic Fluid Technology**, Paul Michael, Milwaukee School of Engineering and John Sherman, BASF

**SYNTHETICS LUBRICANTS 203**
8 am – 5 pm • Room 304

- **Introduction to Synthetic Fluids**, Stephen C. Lakes, Cognis Corp.
- **Polyglycols**, Martin Geaves, Dow Chemical Corp.
- **Silicones**, Sandra Walker, Dow Corning Corp.
- **Polyalphaolesins**, Cindy French, Chevron Phillips Chemical Co.
- **Esters**, Gene R. Zehler, Cognis Corp.
- **Fluorocarbons**, Gregory Bell, DuPont Chemicals
- **Alkylated Aromatics**, Beth Winsett, ExxonMobil Chemical
- **Phosphates**, W. David Phillips, Great Lakes Chemical Corp.
Wednesday May 18

ADVANCE LUBRICATION 301
8 am – 5 pm • Room 302

Wear and Wear Mechanisms, Vivek Palekar, Chevron
Lubricant Additives, Michael Hoey, BASF
Oil Rheology, Low Temperature and Viscosity Modifiers, Michael Covitch, Lubrizol
Novel Lubricants to Improve Fuel Consumption, Ewa Bardasz, Lubrizol

BASIC LUBRICATION 102
8 am – 5 pm • Rooms 305

Gears and Coupling Fundamentals, John Hermann, ExxonMobil
Grease Fundamentals, Paul Grives, ExxonMobil
Seals, Steve Lemberger, Lemberger Consulting Services
Compressors, Instructor to be determined.
Bearings and Lubrication Systems, Paul Shiller, Timken
Basic Engine, Sam Vallas, Chevron
ATF Fluids, Sam Vallas, Chevron

BASIC GREASE (NLGI)
8 am – 5 pm • Room 303

Course Overview and Introduction to Greases, Chuck Coe, Grease Technology Solutions, LLC
Base Oils, Valentina Serra-Holm, Nynas
Grease Manufacturing Overview and Open Kettle Manufacture, David Turner, Shell Global Solutions
Grease Manufacturing Contactor/Kettle and Continuous Manufacture, David Turner, Shell Global Solutions

METALWORKING – HOT TOPICS
8 am – 5 pm • Room 309/310

VOC TGA Methodology Development and Results, John Burke, Houghton International
Overview and Implications for VOC Regulations, Mike Pearce, W.S. Dodge Oil Company
Chemical Additives Review, Neil Canter, Chemical Solutions
Reregistration of Biocides and Microbiology, Fred Passman, BCA, Inc.
Global Harmonized Standard, Safety Data Sheet Overview and TSCA Reform, Rich Kraska, Kraska Consultants, Inc.
Interpreting HMIS From the Formulator’s and the End User’s Point of View, Carol Poole, Primagry Consulting
Safety Update, Regulatory Exposure Limits for Metal Removal Mist, John Howell, Primagy Consultants
High Performance Machining Update, MQL and Green Chemistry, Neil Canter, Chemical Solutions

SYNTHETIC LUBRICANTS 204
8 am – 5 pm • Room 301

Military Applications, Carl E. Snyder, University of Dayton Research Institute
Automotive Applications, Steven C. Lakes
Industrial Applications: Compressors, Gene Finner, Dow Corning Corp.
Metalworking Lubricants and Hydraulic Fluids, Govind Khemchandani, Dow Chemical Corp.

Special FREE Education Course: Nanotribology

OBJECTIVE: Recent advances in nanoscience and nanotechnology are greatly improving our atomic scale understanding of material phenomena and our ability to manipulate materials at nanometer length scales. These advances are leading to many exciting new technologies, devices, and applications. Tribology, in particular, is currently undergoing a revolution, as we finally learn the nanoscale details of how surfaces, interfaces, defects, and atomic structure influence tribological phenomena, and where we see that this information is critical for ensuring that many nanoscale applications function properly and reliably.

This short course provides an introduction to nanoscale tribology, discussing how this field is reshaping our understanding of tribological phenomena and leading to new technology applications. We will cover the principal concepts and applications, drawing connections to both established and new approaches. We will discuss the limits of continuum mechanics and present newly developed theories and simulations, and will discuss experiments that address nanoscale tribological phenomena. These new scientific developments will be illustrated throughout the course with examples of the exciting technology applications being enabled by these nanotribology developments.

The course is jointly presented by Robert Carpick, professor, Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania and C. Mathew Mate, Hitachi San Jose Research Center.

TOPIC SUMMARY
- Overview of Nanotribology – motivation, major advances, and challenges
- Tools of nanotribology: atomic force microscopy, atomistic simulations, and other techniques
- Single asperity friction and atomic stick-slip
- Breakdown of continuum mechanics at the nanoscale
- Behavior of lubricants in tight spaces
- Nanoscale wear
- Applications: Nanoscale surface engineering, MEMS, disk drives, superlubricity
- Summary and future outlook

This course is Sunday, May 15 from 1-5:30 pm and is part of the Nanotribology Division technical session. There is no fee except the annual meeting registration. Funds from the National Science Foundation have been secured to provide travel scholarships for students who wish to attend the course, as well as the rest of the STLE meeting.

Rooms 309/310
Local Section Leader Workshop

Sunday, May 15
5 – 6:30 pm
Rooms 309/310

“How to Create Committee Meetings that Work”

Presented by Drs. Jean & Ed Becker

What organization doesn’t have committees? Do your committees always produce what you want them to? If not, there are things you can do up front to greatly increase the chances a committee will be efficient, effective, and leave everyone with the feeling of accomplishment when the task is complete.

Drs. Jean and Ed Becker will present research on why some committees turn out well and others flounder without ever producing anything useful. You will leave with a new understanding to help you consider whether or not to even appoint a committee. Yes, there are situations where you can predict in advance that a committee will not do as good a job as an individual!

If you decide to appoint a committee, what kind should you appoint? At this workshop, which is open to all AM attendees, you will receive a comprehensive framework to guide your thinking about what you want the committee to do and exactly what kind of a chair, committee, time frame and charge would best produce the work product you envision. By investing time carefully thinking through the committee structure at the beginning, you also will greatly increase the chances your group will be able to make good use of the committee’s work.

At the end of this session, you will:
- Recognize tasks where one person can do the work better than a committee.
- Know which situations require a committee.
- List what the appointing group can do to increase committee success.
- Know how to select committee members and a committee chair.
- Understand the obligations of committees.
- Be able to define the parameters of committee, including types and time frames.
- Clarify the committee’s job to both the committee and the appointing authority.
- Understand the importance of committee goals.
- Better manage the relationship between a committee and the appointing authority.
- Know how to actually use committee results.

Dr. Jean K. Becker owns and operates The Emerald Frog, a management-consulting firm that provides training to for-profit and not-for-profit businesses. She is currently the president of the Michigan Alliance for Gifted Education. Dr. Edward P. Becker, P.E., is a past president and fellow of STLE. He has more than 25 years experience as an officer and leader in technical and social organizations. He has provided training for technical societies and within General Motors. Open to all AM registrants.

Keynote Address

Monday, May 16 • 10:30 am – Noon • Grand Ballroom C/D

Biological Principles and Biomimetics of Tribologically-Active Materials

By Dr. Stanislav N. Gorb, Zoological Institute of the University of Kiel

Why don’t geckos, beetles and flies fall from the wall? In their evolution, they have parallel developed attachment devices of remarkable quality.

The secret is based on the structure and material properties of adhesive and frictional surfaces. Modern high-resolution techniques aided in the structural analysis of these surfaces down to the nanometer scale and precise characterisation of their micromechanical properties.

Recently obtained results are of major interest for technological applications. The basic-oriented research provided essential information for industrial developments of bio-inspired material surfaces with enhanced adhesive and frictional properties, which enabled robots to climb up the wall in thousands of step cycles.

This talk demonstrates how comparative experimental biology approach may help in developing new tribologically active materials.

To present this keynote address STLE is fortunate to have Stanislav Gorb, professor in the Department of Functional Morphology and Biomechanics at the Zoological Institute of the University of Kiel in Germany. Gorb has published nearly 200 technical papers and holds four patents.
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Bryan Huston | (215) 591-3610 | Yein Saechao | (408) 376-4040
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Afton Chemical Corp. | 7 | Chevron Phillips Chemical | 71
Lauren Ereio | (804) 788-6081 | Amy King | (832) 813-4627
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Afton Chemical Corp. | 7 | Compass Instruments/Falex Corp. | 26
Lauren Ereio | (804) 788-6081 | Sherri Leazer | (704) 331-7138
[dbeerhalter@dow.com](mailto:dbeerhalter@dow.com)
Alicona | 82 | Crystal Inc. | 55, 56
Brad Etter | (630) 372-9900 | William Hood | (281) 870-6034
[brad.etter@alicona.com](mailto:brad.etter@alicona.com)
ALS Tribology | 42 | FRT of America | 75
Rhonda Holstien | (281) 599-1242 ext. 301 | Paul Flynn | (408) 261-2632
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ANGUS Chemical | 29 |
Danielle Beerhalter-Leheny | (267) 419-8573 |
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[kristen.hangney@anton-paar.com](mailto:kristen.hangney@anton-paar.com)
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[dnlockett@archchemicals.com](mailto:dnlockett@archchemicals.com)
Arkema, Inc. | 58 |
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Kayanne Chandler | (973) 245-7596 |
[kayanne.chandler@basf.com](mailto:kayanne.chandler@basf.com)
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**Poster 1**

**Wear Performances of Eni-PVD Coated CALDIE for Stamping Advanced High-Strength Steels (AHSS)**

C. Wang, J. Chen, Department of Plasticity, Shanghai Jiao Tong University, Shanghai, Shanghai, China

**Tribotesting**

In the course of stamping or blanking for Advanced High-Strength Steels (AHSS), the high press load required causes severe chipping and adhesive wear. In this study, TiN was coated on conventional die material CALDIE with energetic neutral and ion physical vapor deposition (Eni-PVD) technique. The aim of this study is to investigate the wear performances of both coated and uncoated die material CALDIE using a series of Pin-on-Disc tests. In the experiments, four levels of pressures (2.55MPa, 5.09MPa, 7.64MPa, and 10.09MPa) and four levels of rotation speeds (38.6 rad/s, 56.5 rad/s, 113.6 rad/s and 202.2 rad/s) were adopted. The obtained experimental data were analyzed by regression method. It was observed that the coated die material exhibited much higher wear resistance performances than the uncoated. The analysis also showed that the wear performances were more sensitive to the rotation speed of the pins than the applied pressures for the range used in the experiments.

**Poster 2**

**Hard-facing Basics: Elements of Process Equipment, Thermal Pipes**

S. Smirnovs, J. Rudzitis, Riga Technical University, Riga, Latvia

**Wear**

Are you looking for ways to extend the service life of your process equipment? One of the techniques you can use is called hard-facing, which is depositing wear-resistant surfaces on metal components to extend their life. In many cases, rebuilding equipment is less expensive than the cost of replacement, making hard-facing an attractive option. There are many different items that could potentially benefit from hard-facing that can be placed into three basic “wear” categories – abrasion, impact and metal-to-metal. Abrasion is the most common type of wear.

**Poster 3**

**Surface Texturing on Metallic Cylindrical Surface by Through-mask Electrochemical Micromachining**

X. Hao, L. Wang, Q. Wang, Y. Ding, F. Guo, B. Lu, State Key Laboratory for Manufacturing Systems Engineering, Xi’an Jiaotong University, Xi’an, Shaanxi, China

**Surface Engineering**

The electrochemical micromachining (EMM) technique is proposed to cylindrical fabrication of surface texture. The tin-bronze rod is patterned with photosist through proximity rolling-exposure lithography. The patterned rod is etched with a concentric cylindrical counter electrode with a gap of 17 mm and then micro-grooves or micro-point concaves on rod surface are obtained. In order to ensure the accuracy of shape of microstructures, a 2D exposure model is built to predict and optimize the relationship of the exposure radius, angle and ratio of light intensity. The EMM experiments show that the vertical growth of pores is promoted with regard to the lateral propagation of pores by increasing the current density, and the etched depth nonuniformity is mostly ascribed to the current aggregate effect due to the variety of surface patterning on the cylinder. Furthermore, the ordered microstructures with a feature size down to 20 μm in large-scale on cylindrical surface are obtained.

**Poster 4**

**Effects of Piston Ring Profiles on Lubrication by Theoretical Analyses**

Y. Zhang, T. Wu, Theory of Lubrication and Bearing Institute, Xi’an Jiaotong University, Xi’an, Shaanxi, CHINA; Y. Xie, School of Mechanical Engineering, Shanghai Jiaotong University, Shanghai, China

**Lubrication Fundamentals**

Friction forces of piston rings accounted for 75 percent or more of total piston friction force. In this article, effects of two types of ring profiles, type A and type B, on lubrication between the piston ring and cylinder wall by theoretical analyses were reported. Effects of ring design parameters were also studied. Reynolds equations and flow continuity equations were used to model lubrication including Reynolds boundary condition. A fully flooded inlet condition and axisymmetric geometry were considered. Then a numerical procedure was developed to obtain the cyclic variations of frictional force, and the effects of ring profiles as well as design parameters were examined. The result shows that type A has much higher piston friction loss than that of type B. It is also shown that this analysis can be used to study the influence of ring design parameters in order to improve the piston ring design in engines.
Poster 5

Gamma Radiation and Temperature Effects on Viscosity Index of Turbine Oils

Condition Monitoring
The temperature and gamma radiation effects in the Primary Circuit (PC) of HWPWR should influence the Viscosity Index (VI) of turbine oils. The object was to discriminate between the effects of radiation and temperature on the IV results of HWPWR’s oils. The irradiation experiment was performed in an Experimental Reactor Facility (ERF) with doses equivalent to the PC and at room temperature. The VI results of the ERF’s oils and HWPWR’s oils were compared. The IV of HWPWR’s oils decreased at normal temperature and increased with thermal excursion. The IV changes would be appreciable, under temperature effects. The VI results were related with the infrared spectra of the base oil. The FTIR showed changes at room temperature in the ERF’s oils.

Poster 6

Tribological Properties of Micro-scale Dimpled SKD61 Steel in Lubricated Sliding
A. Auezhan, Y. Pyun, Mechanical Engineering Department, Sun Moon University, Asan-si, Chungnam, Republic of Korea; B. Zhang, CSM Instruments S.A., Peseux, Switzerland

Surface Engineering
This paper investigates the effect of micro-scale dimples (created by Ultrasonic nanocrystal surface modification treatment) on the tribological properties of a silicon nitride ceramic against hardened SKD61 steel under oil lubricated conditions. Tests were carried out over a range of sliding velocities and normal loads using a commercially available tribometer. The emergence of atomic force microscopy (AFM) has helped the development of studies of micro-scale dimple, particularly its diameter, depth and pitch which have been studied extensively. Overall micro-scale dimpled surface showed better tribological properties in terms of reduced friction coefficient compared with an untreated surface. However, surface texturing of the disc specimen surface (micro-scale dimple density between 42.3 and 46.8%) resulted in significant improvement in tribological properties. Some recent trends and speculations about the future end the paper.

Poster 7

Comprehensive Modeling of Hydrogen Embrittlement in Steel Bearings Accelerated by Increased Electrostatic Charges
R.V. Petrach, J. Schall, Mechanical Engineering, Oakland University, Rochester, MI

Wind Turbine Tribology
Hydrogen embrittlement is a leading cause of bearing failures. The exact mechanisms behind the hydrogen-related failures are vague and incomplete. These types of failures are especially common in wind turbine bearings. Studies have suggested that the cause of these issues is related to the high electrostatic charges generated by wind turbines. Other studies have shown electrochemical charging is an effective way to diffuse hydrogen into steel, but there have not been any conclusive arguments linking all these factors together. A hierarchical model is being developed to study of electric field enhanced diffusion and the effect on rolling contact fatigue. The first step is to determine cohesive and shear strength of grain boundaries in the presence of hydrogen using molecular simulation. This data will then be used to inform a polycrystalline finite element to model macroscale fatigue behavior in rolling contacts. Progress to date on the development of the model will be presented.

Poster 8

Modification of MR Fluid to Improve the Tribological Characteristics

Synthetic and Hydraulic Lubricants
Magneto-rheological(MR) fluid is modified by mixing and adding the additives for the better tribological performance. The researches on MR fluid have been active progress all around the worlds, especially for the application to mechanical devices on various fields. However, researches to improve the MR fluid on tribological performance are rarely performed. In this study, the experiments on friction and wear with pin-on-disk tester as well as linear-oscillation tester are conducted to evaluate the modification of MR fluid in different operating condition and magnetic fields. Also, Pressure Differential Scanning Calorimeter is used to evaluate Oxidation Induction Time. Moreover, Scanning Electron Microscopy is used to investigate the microscopic changes of surfaces as well as the MR particles. Subsequently modification effects on the surface roughness and profiles are investigated by using a profilometer. From the results, tribological performance of modified MR fluid is analyzed.
Protein Adhesion to TiN and CrN Coatings
A. Rocha, H. Liang, Texas A&M University, College Station, TX; C. Li, University of Science and Technology Beijing, Beijing, China

Bioritobology
Current artificial joint materials need to be further improved for adhesion and service life. In the present research, the adhesion of albumen protein to TiN and CrN coatings is studied via rotational shear flow. TiN and CrN coatings provide improved wear resistance over pure Ti and Cr. These coatings offer a potential alternative to reduce wear in artificial joints. Previous research has demonstrated that there are two factors that affect protein adhesion: surface roughness and surface chemistry. Here we study effects of material and surface properties of those coatings on adhesion. Experimentally, we developed a test method to quantitatively evaluate the adhesive strength at the protein/material interface. Subsequently we study the interfacial mechanisms between coating surfaces and protein molecules.

“Loc-Lub:” A Novel Method of Lubricant Application to MEMS Devices
J.Y. Leong, S. Sinha, N. Satyanarayana, G. Zhou, Mechanical Engineering, National University of Singapore, Singapore

Nanotribology
Lubrication of MEMS has long been an issue in the industry. Surface forces between surfaces often result in stiction between components, leading to failure of the device and device designs have been made to avoid contact. A novel technique named “Loc-Lub” (patent pending) was invented to deliver a small quantity of lubricant to a specific location on a MEMS device, avoiding contact with other components on the device. Investigation of the effectiveness of the method has revealed that the adhesion forces between the sidewalls have been largely reduced. Devices have shown to exhibit no wear after sliding and maintain the same initial functionality, being able to separate the contact multiple times. This work has been granted U.S. Provisional Patent 61/314,627, filed on 17 March 2010. This work was conducted with the financial support by National Research Foundation (NRF), Singapore (Award No. NRF-CRP 2-2007-04).

Nanoscale Friction and Adhesion Behavior of 2-D Materials
X.Z. Liu, Q. Li, R.W. Carpick, Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA

Nanotribology
Two-dimensional (2D) materials, including graphene, have drawn much attention because of their extraordinary physical properties, making them outstanding candidates for future electronic devices. To date, the mechanical properties of 2D materials have received less attention compared to their electronic and thermal properties, and they remained poorly understood despite their importance in determining the applicability of 2D materials to integrate in various devices. In this work, we studied friction and adhesion between exfoliated graphene sheets and nanoscale single asperity tips using atomic force microscopy (AFM). In particular, we quantified the dependence of friction on load and scan speed, and further explored the mechanism behind the thickness-dependent friction behavior exhibited by 2D films (Lee, 2010). In contrast to friction behavior, we found that adhesion does not change appreciably when the layer number changes. We will discuss the mechanisms behind this phenomenon.

Adhesion Between Graphene and Nanoscale Asperities: Finite Element Simulations
B. Zhang, Q. Li, X.Z. Liu, J.L. Bassani, R.W. Carpick, Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA

Contact Mechanics
Finite element models are developed to calculate the mechanical response of a nanoscale contact between an atomic force microscope (AFM) tip and graphene sheets composed of different numbers of layers. Graphene sheets are considered as individual continuum elastic shells based on the mechanical properties of single graphene layers. The van der Waals forces between all layers, the tip, and the sample are normal tractions given by an effective Lennard-Jones interaction. Three types of frictional interactions between the graphene sheets are considered: infinite friction, finite friction, and zero friction. We determine the loading forces and contact area as a function of tip displacement during elastic indentation of the graphene. The pull-off forces from the simulations are compared with those from the experiment, and the trends are found to be in very good agreement. We also discuss comparisons between the simulated contact area and results from contact mechanics theory.

Characterization of Nanoscale Surface Films in Solid Lubricants
H.S. Khare, D.L. Burris, Mechanical Engineering, University of Delaware, Newark, DE

Materials Tribology
Solid lubricants have been shown to form ultra-thin (~10 nm) tribofilms at sliding interfaces. These films are consistently observed during low wear and low friction sliding, and are believed to have a significant impact on friction and wear. The aim of the present research is to characterize the properties of tribofilms of candidate space lubricants in an attempt to clarify their contributions to macro-scale friction and wear. Transient wear processes and wear track evolutions are measured with optical interferometry and combined with spatially sensitive nanotribological analysis (using lateral force microscopy) to elucidate sliding-induced modification of solid lubricant surface, attributable to formation of tribofilms. The effect of varying surface temperature and operating environment on the stability and characteristics of these films is also explored.

Wear Rates in Different Environments
J. Ewin, B. Krick, A. Bennett, W. Sawyer, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL

Wear
Polytetrafluoroethylene (PTFE) is a popular solid lubricant due to its advantageous properties including low friction coefficient and chemical inertness; however poor wear resistance limits its use. Previous studies have shown that the wear resistance of PTFE can be increased by orders of magnitude with the inclusion of fillers; some composites having wear rates lower than 1x10^-8 mm3/Nm. The origin of the ultra low wear behavior of these composites has been explored by many research groups but is still not fully understood. Chemical changes have been observed in the composites at the interface. This work investigates chemical changes believed to be the source of the ultra low wear phenomenon in low wear PTFE composites.
Wear Prediction in Ionic Solids Based on Coulombic Interactions  
K.R. Marchman, B.A. Krick, W. Sawyer, R.S. Colbert, University of Florida, Gainesville, FL  

Wear  
This study attempts to form a quantitative comparison of wear rates in ionic solids based on the Coulombic potential energies of their molecular interactions. It is proposed that the higher the Coulombic potential between atoms of a species, the lower the wear rate will be. Pin on disk tribological tests were performed on several different ionic solids. These tests provided quantitative wear rate data for comparison. Experiments were conducted on ionic solids with similar crystal structures so that the Coulombic potential calculations would be comparable. It was found that general trend between low wear rates and high Coulombic potentials exists.

Friction Mitigation in Nanocrystalline ZnO via Subsurface-Induced Plastic Shear  
H. Mohseni, B. Mensah, N. Gupta, S. Srivilliputhur, T. Scharf, Materials Science and Engineering, University of North Texas, Denton, TX  

Materials Tribology  
Experiments and density functional theory (DFT) calculations reveal atomistic origins of low friction and nanocrystalline plasticity when sliding along ZnO textured (0002) nanocolumnar grains. The atomic layer deposited sub-stoichiometric ZnO film was structurally tailored to achieve low surface energy and low growth stacking fault energy basal planes. Sliding on this defective ZnO structure resulted in an increase in both partial dislocation and basal stacking fault densities through intrafilm shear/slip of partial dislocations on the (0002) planes via a dislocation glide mechanism. This shear accommodation mode mitigated friction and prevented brittle fracture classically observed in higher friction microcrystalline and single crystal ZnO, which has potential broad implications to other defective nanocrystalline ceramics. High resolution transmission electron microscopy inside worn surfaces revealed these underlying mechanisms responsible for low friction.

Analysis of Losses Associated with Internal Combustion Engines due to Engine Oil Contamination  
J. Wallace, J. Hennings, A. Mitra, Mechanical and Electrical Engineering Dept., Georgia Southern University, Statesboro, GA  

Engine & Drivetrain  
Energy loss due to friction associated with Internal Combustion Engines is a key factor for determining the efficiency of the mechanical system. While proper engine lubrication is essential, the engine oil progressively becomes contaminated by fuel in its operating condition, especially with bio-fuels. The objective is to quantify the engine oil properties when it is contaminated with E85/Butanol fuel and run the engine simulation using FEV Virtual Engine software. A study is performed to discover the contamination level effects of various engine oils on the frictional losses. Simulation results for a small displacement SI engine indicate that the frictional losses in the hydrodynamic crankshaft main bearings, hydrodynamic crank-pin bearing, and the hydrodynamic thin film piston to cylinder interaction, are affected by the oil viscosity changes. The frictional losses and the oil viscosity appear to have an inverse relationship for the viscosities tested and contamination levels.

Validation of a Small Engine-based Procedure for Studying Engine Lube Oil Performance  
W.F. Rohr, K. Nguyen. Mechanical, Aerospace, and Biomedical Engineering, The University of Tennessee, Knoxville, TN; B. Bunting, National Transportation Research Center, Oak Ridge National Lab, Oak Ridge, TN  

Engine & Drivetrain  
Engine friction is a complex subject and is affected by lubricant viscosity, additives, engine pressure, engine speed, and engine design. Lubricant performance is typically evaluated using devices which simulate single engine components and full-fired engine tests. The former provides insight to performance for the emulated component but does not offer a complete picture for real engine conditions. Full-fired engine tests do provide real engine data but at a high cost and high complexity. This study seeks to bridge this gap by providing a relatively simple, inexpensive device based on a small, single cylinder engine which examines lube oil performance via motoring torque and oil viscosity. This setup also allows for relatively easy removal or addition of components to isolate sources of friction or simulate a full engine test. Currently, the device is operated with the tappets removed and oil circulated via an external oil pump to focus on piston/liner friction.

Tribology of Bio-Lubricants  
D.R. Huitink, Y. Zhou, H. Liang, Mechanical Engineering, Texas A&M University, College Station, TX  

Biotribology  
Biological systems exhibit the capacity to self lubricate and form protective coatings via the generation of oils and waxes. These lubricants can assist in locomotion, as in the case of gastropod mollusks. To understand these unique biological fluids, a tribological study of their lubrication properties has been performed and compared with common gear oil and greases. A rheometry study of the viscous nature of the biolubricants was performed, in addition to ball-on-disk and plate-on-plate tribo-tests for characterizing the frictional behavior of the fluids as lubricants. It was found that the mucus of a common slug, which contains proteins that behave both as a liquid lubricant or a semi-solid adhesive, exhibits shear-thinning behavior that transitions between grease-like viscosity and something similar to gear oil at higher shear rates. Furthermore, the frictional response reflects these properties in exhibiting higher friction at low speeds and conversely at high speeds otherwise.
Poster 20

Mechanical Analysis of Transfer Film Formation with Polyamide-imide
A.I. Bennett, R.S. Colbert, B.A. Krick, G. Sobolevskiy, W. Sawyer, Mechanical and Aerospace, University of Florida, Gainesville, FL

Materials Tribology
Polyamide-imides (PAI) are an ideal candidate for solid lubricants because of their exceptional mechanical, thermal, and chemical resistant properties. Stable transfer films are critical to the tribological performance of these polymers. PAI transfer films on glass, nickel, and steel substrates were characterized using scanning white light interferometry, stylus profilometry, and Raman spectroscopy. In situ experiments were performed using optical microscopy and scanning electron microscopy in conjunction with energy dispersive X-ray spectroscopy.

Poster 21

Chemical Structure and Reaction Mechanism of Thermally Polymerized Vegetable Oils
M. Arca, J.M. Perez, Chemical Engineering, Pennsylvania State University, University Park, PA; B.K. Sharma, Illinois Sustainable Technology Center, University of Illinois at Urbana Champaign, Champaign, IL; K. Doll, Bio-Oil Research, NCAUR, ARS, USDA, Peoria, IL

Environmentally Friendly Fluids
In the literature many methods are suggested to calculate oxidative properties of base fluids. Thermal Gravimetric Analyzer (TGA), Pressure Differential Scanning Calorimeter (PDSC) and Penn State Micro Oxidation System (PSMO) are common methods to study oxidative properties of lubricants. The use of vegetable oil based lubricants is increasing rapidly. Vegetable oils have good lubricity, wear protection and low volatility. However they have low thermal-oxidative stability and high deposit formation tendency. In this study the oxidative properties of soybean oil is studied as typical of vegetable oil based lubricants. Thermal stability and deposit formation characteristics of soybean oil are studied by isothermal TGA, PDSC and PSMO. Heating rate, catalysis, isothermal time, purge flow and oxygen diffusion are studied at different temperatures. Correlation between the test methods is shown.

Poster 22

Tribological Evaluation of Titanium and Aluminum Alloys Exposed to Hydrogen in Wet Conditions
S. Joo, H. Liang, Mechanical Engineering, Texas A&M University, College Station, TX; M. Sanders, Stress Engineering Services, Inc., Houston, TX

Tribotesting
Manufacturing process of titanium and aluminum alloys in wet hydrogen condition motivated this work on mechanical and tribological behavior of hydrogen charged materials. For sample preparation hydrogen charging method was developed. For mechanical and tribological analysis small punch test and tribometer were used respectively. XRD (X-ray Diffraction) results showed that the formation of hydride didn’t occur for both materials. The hydrogen molecular didn’t have any visible effect on the mechanical property of aluminum alloy; however, titanium alloy showed reduction in the strength. The tribological results showed that there was no significant effect on both materials in terms of friction and wear. The current research shows a novel way to test for the effects of hydrogen in wet conditions on the mechanical strength of materials. The research outcome could aid design engineers in their selection of materials in hydrogen environments.

Poster 23

A Study of Repeatability of Friction using Molecular Dynamics Simulation
C. Nagolu, J. Schall, Mechanical Engineering, Oakland University, Rochester, MI

Contact Mechanics
Due to complexity in friction and wear mechanisms, measurements of friction are known to show significant variability from experiment to experiment. In this work, a study of repeatability was conducted using molecular dynamics (MD) simulation. In these simulations, all variables are held equal (material, lubricant, velocity, temperature, load) with the exception of a single random number seed used to populate a Boltzmann distribution of atomic temperatures. Six simulations at three selected loads were performed. The data shows lower standard deviation but higher relative error at low loads versus high loads. At low loads, the surfaces remain atomically smooth with the octane providing lubrication. At the highest load, surface roughening creates asperities and introduces metal to metal contact. These processes are random and introduce significant variability in the friction force. However, no average friction force lay outside the standard deviation of any other trial at the same load.

Poster 24

Characterization of Debris from Molybdenum Disulphide Films in Various Environments
K.G. Rowe, R.S. Colbert, W. Sawyer, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL

Materials Tribology
Molybdenum disulfide (MoS2) based films remain one of the most common solid lubricants in the aerospace industry. While numerous studies have focused on the tribological performance and properties of various coatings, little attention has been given to the characterization and quantification of the generated wear debris. Testing was performed on a linear reciprocating tribometer with a small environment chamber which encapsulated the sample and the pin to reduce the sampled volume of gas and to better control the humidity in the environment. The generated debris was sampled by a LasAir II particle counter with particle size channels 0.1, 0.2, 0.3, 1, and 5 µm. A stream of filtered environment gas impinged upon the surface of the film to aerosolize the generated wear debris. This study examines the effects of humidity on the concentration and size distribution of aerosolized particles generated from the tribological testing of MoS2 based films.
Approach for Modeling Multiphase Flows

Traditionally, there have been two ways to model multiphase flows. The Eulerian-Eulerian approach, in which the phases are modeled as interpenetrating continua, is computationally efficient but does not provide discrete particle locations. The Eulerian-Lagrangian approach treats the dispersed phase as individual particles interacting with a fluid continuum. Yet, this approach is computationally demanding, especially for high solid fraction flows. This work introduces an Eulerian-Lagrangian approach to modeling multiphase flows, in which the particles are modeled using cellular automata (CA). In this Eulerian-CA approach, the fluid is modeled on a lattice. This approach can be easily extended to model the tribology of multiphase flows interacting with surfaces, including wear analysis. This work performs an examination of the feasibility of this approach for modeling multiphase flows while achieving significant computational speedups.

Contact Lens Lubrication in the Context of the Stribleck Curve
J.M. Uruêna, A.C. Dunn, W.G. Sawyer, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL

As soft contact lens friction testing methodologies have developed, there is increased need for comprehensive trends in contact lens friction. This study examines 4 commercial lenses under a wide range of sliding speeds (20-3600 µm/s) and normal loads (2-150 mN) in isotonic saline at 34°C. Friction decreases an average of 27.0% over this range of sliding speeds; characteristic shear stresses for each lens surface were identified (1.1 kPa for p-HEMA and 0.5-2.5 kPa for silicone lenses). Measured penetration depth was used to calculate the areas of contact. Also, in situ optical microscopy in a microtribometer was used to identify the lubrication regimes from boundary to hydrodynamic during sliding between a hydrogel and glass surface. This range of testing parameters and in situ images of hydrogel surface contacts has illustrated that friction trends generally follow a Stribleck-type curve, and these studies help to contextualize the existing body of soft contact lens friction data.

Rate Dependent Deformation Response of Articular Cartilage
E.D. Bonnevie, V. Baro, L. Wang, D.L. Burris, Mechanical Engineering, University of Delaware, Newark, DE

The progressive breakdown and failure of articular cartilage as seen in Osteoarthritis is currently one of the leading causes of severe disability in the United States. Historically, tribological studies of cartilage displayed a time dependent friction coefficient, starting low (µ~0.01) and increasing to a steady state value (µ~0.2). One recent study showed that a constant deformation rate to the cartilage structure during sliding induced fluid pressurization leading to sustained low friction. To further analyze the conditions leading to fluid pressurization, this study experimentally analyzes the spherical contact problem to determine: 1) If Hertzian mechanics can be used to describe the response, 2) If there is a depth dependence or substrate effect on the aggregate modulus, 3) How the deformation rate affects the force response, 4) What role the interstitial fluid plays in the response.

An Eulerian, Lattice-based Cellular Automata Approach for Modeling Multiphase Flows
M.C. Marinack Jr., J.N. Mpagažehe, C. Higgs III, Mechanical Engineering, Carnegie Mellon University, Pittsburgh, PA

Traditionally, there have been two ways to model multiphase flows. The Eulerian-Eulerian approach, in which the phases are modeled as interpenetrating continua, is computationally efficient but does not provide discrete particle locations. The Eulerian-Lagrangian approach treats the dispersed phase as individual particles interacting with a fluid continuum. Yet, this approach is computationally demanding, especially for high solid fraction flows. This work introduces an Eulerian-Lagrangian approach to modeling multiphase flows, in which the particles are modeled using cellular automata (CA). In this Eulerian-CA approach, the fluid is modeled on a lattice. This approach can be easily extended to model the tribology of multiphase flows interacting with surfaces, including wear analysis. This work performs an examination of the feasibility of this approach for modeling multiphase flows while achieving significant computational speedups.
Poster 30

**Atomistic Simulation Study of Frictional Behavior of Multi-Layered Graphene**
A. Udupa, A. Martini, Mechanical Engineering, Purdue University, West Lafayette, IN;

**Nanotribology**
Using molecular dynamics simulation, we studied the frictional characteristics of atomically thin graphene sheets. A model capable of capturing non-bonded interactions as well as the forming and breaking of covalent bonds was used. We modeled the scanning of an AFM tip over graphene of various thickness. We were able to reproduce the results from experimental studies, namely the decrease in friction with increase in number of graphene layers. We further use our simulations to propose a hypothesis based on a mass-spring model to explain the observed behavior. The atomistic simulations and mass-spring model give insight into the atomic-scale mechanisms underlying the observed frictional behavior.

Poster 31

**Investigation of Surface Modification in an Axial Piston Pump**
A.T. Cross, F. Sadeghi, METL, Purdue University, West Lafayette, IN

**Surface Engineering**
This investigation of an axial piston pump will concentrate on the surface contact between the cam plate and its retaining ring. The addition of micro-pockets to the retaining ring’s surface has proven to reduce friction and wear through hydrodynamic lubrication. An analytical model was developed to generate a design curve for the pocket geometry. An experimental test rig was designed to corroborate the model’s conclusions. Both investigations conclude that with the optimal geometry an upwards of fifteen percent reduction in friction can be seen through the addition of micro-pockets.

Poster 32

**Compressibility of Confined Thin Films using Atomistic Simulation**
A. Vadakkepatt, A. Martini, Mechanical Engineering, Purdue University, Lafayette, IN

**Nanotribology**
In this work, we employ molecular dynamics simulations to investigate the influence of molecular structure of model lubricants on compressibility. The model system consists of various initial film thicknesses confined between atomically smooth parallel walls and subject to a wide range of loads. Compressibility of the model system is characterized using peak to peak density and total density methods which have been reported previously. We also compare the MD predictions to those of the empirical Tait compressibility model and evaluate the differences in terms of the molecular structure. In the process, we develop general guidelines for conducting MD simulations to assist in characterizing the compressibility of bulk fluids.

Poster 33

**Development and Validation of Methods for Testing Lubricants in a Stamping Process for Sheet Steel**
T. Luz, T. Juan, M. Demófilo, Universidad de Monterrey, Monterrey, Mexico

**Practical Lubrication Practices**
The investigation presents the evaluation of some lubricants that are using in the chassis production, specifically in the process of dubbling. The lubricants depend on the type of the process, for a company is complicated evaluate them in plant because if they do not satisfy the company needs and quality, these can affect the tools as well as work pieces and that may cause a big loss for the company. The development of the methodology consists of choosing the tests in tribological machines (T-02 Machine of Four Balls and T-05 Machine of Block-on-Ring) to be able to determine which of the lubricants is the best option. According to the qualities of the lubricants, the machine T-02 works like a filter because it can provide us which of these lubricants presents the best qualities for prevent wear, nevertheless this test is not sufficient because for a best result we need simulate the processes (machine T-05) and compare if the lubricants act according to the previous results.

Poster 34

**A Uniform Layer Model for Lubricants Deposit Formation**
S. Kouame, J. Perez, R. Vander Wal, Pennsylvania State University, State College, PA

**Tribotesting**
Deposit formation from lubricants degradation is universally recognized as undesirable. Across several formulations including mineral, synthetic and bio-based oils, the Penn State Micro-Oxidation test has shown that mass deposition; regardless of the nature of the lubricant follows a similar trend. A lacquer or varnish type of deposit initially forms followed by its proposed transformation to a dark carbon deposit. Yet each of these very different types of deposits results from degradation of the same lubricant. Varnish/lacquer and dark carbon occur when hydrocarbons undergo polymerization and deposition leading to a tenacious (resin-like) film. As a basis to understand and combat deposit formation from the decomposition of lubricants on metal surfaces, the current studies aims to verify a uniform layer deposition model. Specific tasks include a combination thermal and oxidative degradation tests wherein metal coupons were exposed to practical fuels and lubricants in reactor systems.
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