3G - TRACK 12 Environmental Tribology Symposium Co-sponsored by the Chinese Tribology Institution (CTI)

Track Chair: **Jianbin Luo**, *State Key Laboratory of Tribology, Beijing, China*
Track Co-Chair: **Edward Becker**, **Xinping Yan**, *Wuhan University of Technology, Wuhan, China*

ENVIRONMENTAL TRIBOLOGY 1

8 – 11:30am - Mason II
Session Chair: **Michael Nosonovsky**, *University of Wisconsin-Milwaukee, Milwaukee, WI, United States*

8 – 8:30am
Tribochemistry and Lubricity of Vegetable Based Colloidal Lubricants Under Severe Tribological Conditions
IJTC2010-41242
***Kuldeep Mistry, Jong Kim, Naohiro Matsumoto, Hiam Chipman, Osman Eryilmaz, Ali Erdemir**, Argonne National Laboratory, Argonne, IL, United States*
There have been several published reports on the superior tribological performance of nano-colloidal lubricants comprising of different nanoparticles
like: molybdenum disulphide, tungsten disulphide, graphite, boron nitride and boric acid under extreme mechanical conditions. Vegetable oils are highly polar in nature and can enable long term dispersibility of these nano-particles if blended together. Thus, combination
of environmentally friendly_ vegetable based oils and solid nano-lubricants dispersed as a colloidal lubricant could be the way forward in
attaining superior tribological performance with minimal usage of sulfur, phosphorous, and other harmful additives. In the present work, submicron
Boron nitride based vegetable oils were blended and tested in a ball-on-disc test-rig and a high frequency reciprocating rig to evaluate
the tribological performance mainly: friction-coefficient and wear. Post-test surface analyses were carried out to investigate tribochemical
interactions of colloidal lubricants with the steel contact surface. Wear was measured using optical profilometry and wear mechanism was
observed using electron microscopy. The chemical characterization of the tribofilms was investigated using ToF-SIMS (Time of Flight -
Secondary Ion Mass Spectroscopy) and XPS (X-ray Photoelectron Spectroscopy). It was observed that polar vegetable oils prevented
suspension of sub-micron Boron Nitride particles based lubricants and thus improved the long term dispersibility of the particles. Moreover, the
dispersibility of Boron nitride particles enhanced durable tribofilm formation that offered significantly improved performance in terms of friction
and wear than conventional lubricants. Overall, the results of our systematic study demonstrated that colloidal lubricants can further enhance
the lubricity of oils and may help reduce the uses of sulfur and phosphorous-bearing additives.

8:30 – 9am
Tribological Behavior of Textured Surfaces Under Water Lubrication
IJTC2010-41279
***Tianmin Shao, Ximei Wang, Yunyou Lu**, Tsinghua University, Beijing, China*
Being an environment-friendly liquid, water frequently behaves as lubricant in many mechanical systems. However, comparing to the
conventionally used oil lubricants, the film forming ability is poor due to its low viscosity, lead to the early failures of the frictional components.
It has been recognized that tribological behaviors could be effectively improved, by fabricating desirable surface patterns. In the present study,
surface textures with different sizes and area densities were produced. Line cutting, laser machining and masked deposition were employed,
respectively. Friction and wear behaviors of the textured surfaces under water lubrication were experimentally investigated. Test results were
compared to that of un-textured surface. It was found that under water lubrication, friction coefficients of textured surfaces were higher or lower
than the un-textured surface, depending on the test conditions, the size and area density of surface textures. However, wear performance for
most of the textured surfaces tested in the present study was improved compared to that of the un-textured surface. Surface analysis and
contact analysis were made and explanations were suggested based on the results of the analyses.

9 – 9:30am

The Film Formation Mechanism of High Water-based Emulsion

IJTC2010-41283

Jianbin Luo. Liran Ma*, Tsinghua University, Beijing, China*

The oil-in-water emulsion has been widely used as lubricant in metal working such as metal rolling and cutting. The film formation ability of
emulsion was considered as an important factor for evaluating the lubricating effectiveness. Although the film formation characteristics have
been widely investigated, the mechanism is still not well understood. Furthermore there were seldom results reported on the emulsion with an
oil volume percentage less than 1%. The film formation characteristic of emulsions with ultra-low oil concentration (0.005vol%) between a
smooth plate and a highly polished steel ball was investigated. The effects of oil concentration and emulsifier concentration were investigated.
New viewpoints on the film formation mechanism of emulsion were proposed.
Tuesday Morning

9:30 – 10am

Innovative Design of Water-Lubricated Rubber-Metal Composite Bearings and Investigation of Their Mixed-Lubrication Behavior

IJTC2010-41305

Jiaxu Wang, Fanming Meng, Ke Xiao, Guangwu Zhou*, Chongqing University, Chongqing, China*

Powertrain/drivetrain systems operating under severe environmental conditions constantly impose great challenges to components design
engineers. These systems include those for marine propulsion, hydraulic and nuclear power generation, mining and construction, ocean
exploration and various military applications. Water-lubricated bearings are typical components widely used under such conditions. In this
paper, an innovative design method is presented for newly invented rubber-metal composite bearings that have demonstrated improved
performance, reliability, efficiency and energy conservation, as well as reduced vibration and noise, based on the application of rubber-metal
composite bushing materials in replacement of conventional rubber or metal. A mathematical model is developed for this type of bearings,
consisting of the Navier-Stokes and elasticity equations plus associated dynamics. By using the model, mixed-lubrication behavior of the
bearings are investigated numerically at different eccentricities and speeds. Obtained results include water film thickness, hydrodynamic and
contact pressures, load-carrying capacity, friction coefficient and bearing surface deformation. A parametric study for design optimization
reveals that at large eccentricity ratios a reduced fillet radius with the inner surface of bushing may be helpful for improving load-carrying
capacity, and its influence increases with decreasing bushing thickness. For the same nominal clearance, the lower the elastic modulus of
bushing material, the smaller the load-carrying capacity. Also, a FEM analysis for dynamic contact characteristics of the bearing is conducted.
Numerical results show that the maximum values of stress, strain and surface displacement due to contact are usually located at both ends in
bearing width direction, or the downstream along the rotation direction on the bottom plane of the bearing.

10 – 10:30am – BREAK

10:30 – 11am

General Motors' Dexos Global Engine Oil Specification

IJTC2010-41309

Eric Johnson*, General Motors, Milford, MI, United States*

This paper will discuss the history and development of General Motors' first global engine oil specification - dexos. General Motors hopes that
the dexos specification will increase the rate of innovation in engine oil technology. General Motors conceived of the idea of a global engine
oil specification in 2006 and this paper will track the milestones and goals of this specification. Ongoing goals such as increasing fuel
economy and longer drain intervals will be discussed as well as the dexos program from an administrative process.

11 – 11:30am

Tribological Research Towards Environmentally Friendly Air-Conditioning and Refrigeration Compressors
IJTC2010 Technical Presentation Only.

Andreas A. Polycarpou*, University of Illinois at Urbana-Champaign, Urbana, IL, United States*

Tribology has emerged as one of the fields that contribute to the solution of environmental problems through the development of products and
solutions less hazardous or harmful to the atmosphere. The air-conditioning and refrigeration industry has addressed this issue of greener
technology shifting its attention towards advanced compressors that use environmentally friendly refrigerants and oil-less conditions. Such
solutions not only represent cleaner technologies, but would eliminate the adverse thermodynamic effects of the oil present in the refrigeration
cycle. In regards to environmentally friendly refrigerants, researchers have been investigating alternative refrigerants with minimal Global
Warming Potential (GWP) as a replacement to the existing refrigerants. Carbon dioxide, CO_2 (refrigerant designation R744) has shown
significant promise as it is a natural refrigerant, has no ozone depleting potential and negligible global warming potential (GWP=1). Note that
CO_2 for refrigeration comes from existing, mostly natural sources such as the fermentation process in breweries. The widespread usage of
CO_2 as a refrigerant has not happened primarily due to compressor design issues, including tribological issues. Compounded with the use of
CO_2 as a refrigerant is also the desire to reduce and possibly eliminate altogether the oil from compressors. Development of oil-less
compressors requires the implementation of advanced materials, able to withstand unlubricated sliding conditions while maintaining friction
and wear at acceptable levels. Significant advances on the application and deposition of coating materials have been seen in the last decade,
and recent attention in air-conditioning and refrigeration compressors have also been in investigating different coating technologies. These
include both hard coatings as well as polymeric-based coatings, which is be summarized in this work.

4F - TRACK 12 Environmental Tribology Symposium (co-sponsored by the ChineseTribology Institution (CTI))

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ENVIRONMENTAL TRIBOLOGY-2

2 – 5:30pm - Mason II
Session Chair: **Tianmin Shao**, *Tsinghua University, Beijing, China*

2 – 2:30pm
Tribo-Electric Behaviors of Copper under Dry Sliding Against Cu-Cr Alloys
IJTC2010-41292
Zhang Yongzhen, *Henan University of science and technology, Luoyang, Henan, China*
The tribological and electrical conduction behaviors of copper under dry sliding against copper-chromium alloys were investigated on the basis
of simulation tests. The experimental results show that electrical current and trbological parameters have combined effects on both electrical
conduction ability and trological properties. High sliding velocity and electrical current density deteriorate both the tribological and electrical
conduction properties in tribo-electrical sliding system. In the end, Worn surface analysis suggests frictional and electrical resistance heating,
electrical arc spoiling are the main factors to influence the tribological and electrical conduction properties.

2:30 – 3pm
Low Friction Carbon Films for Engine Emission Reduction
IJTC2010-41293
Junyan Zhang, *Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou, China*
Along with the requirements for engine energy saving and emission reduction, especially the restriction of the emission reduction, is harsher
and harsher; many approaches have been developed to achieve the aims.among them, to reduce the friction coefficient of engine frictional
parts to save energy and reduce emission is becoming more and more important because a lager part of engine combustion work (20%~45%)

is consumed to overcome friction work. Furthermore, the successful application of high pressure common rail fuel system demands low friction
and high wear resistance for pin and needle valves. The fullerene-like nanostructure hydrogenated carbon films with high hardness and high
elasticity exhibit super low friction underambient condition with 20% relative humidity. With the application of super low friction carbon films,
the friction coefficient could be reduced to one of sixth. The preliminary test indicates that the super low friction carbon films is able to provide
reliability for high pressure common rail fuel system and reduce the emission 2-5%. It is believable that the employment of the super low
friction carbon films on the frictional parts of engine is one of the economical and timely ways for engine energy saving and emission
reduction. To investigate the relative adaptability of lube to carbon films to choose lube will expand and ensure the application of carbon films
to most frictional parts of engine, and thus to reduce the emission as much as possible.

3 – 3:30 – BREAK

3:30 - 4pm

Analysis of Used Engine Oil and Study on Possibility of Its Regeneration by Additive Method

IJTC2010-41295

Jian Li, Jianfang Liu*, Wuhan Research Institute of Materials Protection, Wuhan, China*

In 2010, the car ownership in China reached 55 million. Suppose each car replacing 5 liters engine oil every year, the annual waste lubricating
oil will get to 270 million liters in China, which is a great renewable resource. If not properly recycled and reused, it will harm the environment
seriously. In the paper, five types of gasoline engine oils were analyzed, including fresh engine oils and used oils correspondingly. Based on
measuring of their total acid values, element contents, particulate contaminations and tribological performances, the differences between the
performances and element contents of all kinds of fresh engine oils with waste engine oils were compared, and the correlation of elements
change with additives of waste lubricating oils was analyzed. The results show that the acid values and particulate contaminations of waste
engine oils increase significantly compared with the fresh oils, because of the consumption of additives, for example extreme pressure
additives, dispersants, etc, oxidation effect of friction chemical reactions, abrasion of friction pair materials and its chemical reaction with
lubrication additives. The consumption of extreme pressure additives and the increasing of particulate contamination lead the extreme
pressure value (PB value) of waste engine oils to fall, wear scar diameter and friction coefficient to increase. The tested waste engine oils still
had a certainamount of raw additives and the performances of anti-extreme pressure, anti-wear, reducing friction and lubricating. It is possible
to make the waste engine oils regenerated by filtering pollution particles (oxidation products, etc.), and supplying reproductive additives and
dispersants.

4 – 4:30pm

A New Mechanism for Squealing Noise and Friction-Induced Vibrations in the Railway Industry

IJTC2010-41296

Guangxiong Chen, Zhongrong Zhou*, Southwest Jiaotong University, Chengdu, China*

In the paper, a new mechanism for squealing vibration based on the time delay concept of friction is introduced. Firstly, several test results on
the time delay between the varying normal force and the consequent varying friction are presented and discussed. Secondly, the motion
stability of a friction system with the time delay is analyzed in theory. The result shows that the friction system may become unstable in the
presence of the time delay. Thirdly, the advantages and disadvantage of the new mechanism are discussed. The remaining part of the paper
will present several research advances in the application of friction-induced vibration theory in the railway industry. In the authors work, a finite
element model of friction self-excited vibration of a railway wheelset-track system is established. The motion stability of the model is analyzed.
Numerical results show that friction between the wheel and rail easily causes self-excited vibration of a railway wheelset-track system. The
relation between the rail corrugation and friction-induced vibration is discussed. Finally, the field test results in Subway line 4 of Beijing are
presented. The test results show that there exists self-excited vibration of a railway wheelset-track system when vehicles negotiate sharp
curved tracks.

4:30 – 5pm

Towards the Green Tribology: Biomimetic Surfaces, Biodegradable Lubrication, and Renewable Energy

IJTC2010-41157

Michael Nosonovsky*, University of Wisconsin-Milwaukee, Milwaukee, WI, United States*, ***Bharat Bhushan****, Ohio State University, Columbus, OH, United States*

The Green Tribology is a new concept that was suggested in 2009. We discuss the scope of the new discipline and the publications on Green
Tribology which are to appear in 2010 and 2011. The three areas relevant to Green Tribology are: (i) biomimetic and self-lubricating materials /
surfaces (ii) biodegradable and environment-friendly lubricants (iii) tribology of renewable and/or sustainable sources of energy. The hypothesis is that these three areas can benefit from each other and, therefore, it is justified to combine these three areas into the novel field
of Green Tribology. We discuss recent theoretical, modeling, and experimental research in these areas of interest and present theoretical,
modeling, and experimental results in the area of environment-friendly tribology.

5 – 5:30pm

Analytic Study of Lubricity of DME Fuel as Alternative Fuel

IJTC2010-41323

Young-Kwan Lim, Jong-Ryeol Kim, EuiSoon Yim, ChungSeop Jung*, Korea Institute of Petroleum Management, Chungbuk, Korea (Republic)*

In recent years, there have been increased concerns about global warming and exhaustion of resources caused by the heavy consumption of
fossil fuel. For this reason, biomass as a renewable source of energy has attract the attention of the research community. In this particular
area, the DME (dimethyl ether) fuel produced from biomass, biogas, and coal is expected to be useful as one of the eco-friendly synthetic fuel
alternatives to petrodiesel. Diesel engines need fuel lubricity due to their severe condition (high pressure and temperature) but DME has low
lubricity. In this study, a analytic system is developed for DME lubricity tests, which are done in a pressurized chambered tester. Various
biodiesel are synthesized from 12 vegetable oils under a base catalyst system. Oxygen compounds have definitely contributed to the natural
lubricity of fuel; biodiesel have a ester group which is a polar oxygenated functional group. The lubricity of neat DME, neat biodiesels, and DME-lubricant blended (100 ppm to 5 vol.%) fuel have been tested and analyzed.