Digital Solutions for Tribology – The Journey to Net Zero

8 November 2024

Institute of Physics, London, UK

iop.org

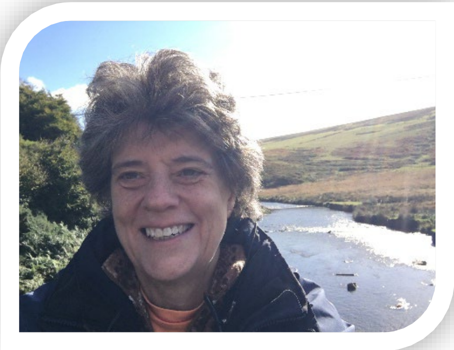
Institution of MECHANICAL ENGINEERS

IOP Institute of Physics

Organising Committee

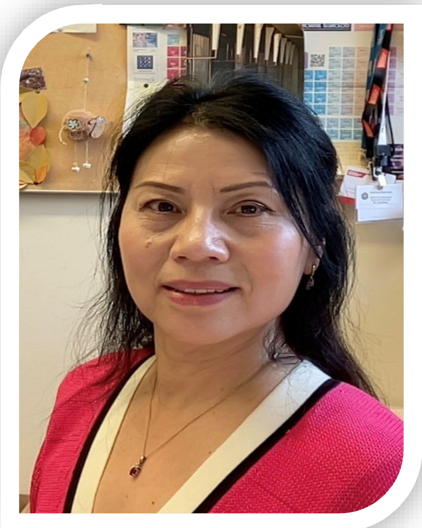
- Dr Shahriar Kosarieh, Member of the IOP Tribology Group Committee
- Prof Honor Powrie, Deputy Chair IMechE Tribology Group Committee, Member IOP Tribology Group Committee
- Prof Ian Sherrington, Chair of the IMechE Tribology Group Committee
- Prof Ling Wang, Chair of the IOP Tribology Group Committee

Professor Honor Powrie FREng, FInstP, Sr Director Data Science & Analytics, GE Aerospace



Honor Powrie has worked in the Aviation Industry for more than 30 years and is renowned for her expertise in Tribo-sensing, Machinery Health Monitoring and Asset Management. Honor currently leads GE Aerospace's UK Data Science Group, delivering innovative AI/ML based solutions for managing Aviation assets. Honor is also Hon RAEng Visiting Professor in Data and Analytics, Asset Condition Monitoring and Management at the national Centre for Advanced Tribology at Southampton (nCATS), University of Southampton.

Professor Ling Wang, Chair of IOP Tribology Group Committee, nCATS, University of Southampton



Ling is Professor of Tribo-Sensing at the national Centre for Advanced Tribology at Southampton (nCATS), University of Southampton. She has over 25 years research experience in the field of tribology and sensing and published over 100 research papers in relevant areas. Her research focuses on tribology of rolling contact fatigue; novel sensing techniques for tribological contacts; and intelligent tribological systems using machine learning methods. She is Fellow of British Institute of Non-Destructive Testing (BINDT) and chairs the Tribology Group Committee at Institute of Physics since 2022. She won the 2017 BINDT COMADIT Prize and the 2021 IMechE Donald Julius Groen Prize.

Programme

09:00	Registration, tea, coffee and networking
10:00	Welcome address
10:05	Talk 1: Using machine learning to help monitor sliding interfaces Dr Tom Reddyhoff, Imperial College London
10:35	Leaves on the line: simulating low adhesion braking performance of trains Dr Julian Stow, University of Huddersfield, Institute of Railway Research
11:05	Coffee Break
11:30	Tribology Testing and Data Models Dr Gordon Lamb, BP, Advanced Lubricant Products
12:00	Molecular Simulations in Tribology: Towards the Virtual Screening of Lubricants Dr James Ewen, Imperial College London
12:30	**Panel Session 1: Delivering reduced carbon footprints through wear and friction reduction**
12:45	Lunch and networking
13:30	Digital Transformation in Oil Condition Monitoring (OCM) Mr Ryan Manthiri, Shell Global Solutions
14:00	Revealing different crack growth conditions in twin-disc specimen and full-scale rail through finite element analysis Dr Marius Gintalas, Brunel University London, NSIRC
14:30	Tea Break
14:55	Advanced Sensing and Data Processing Using Machine Learning in Laboratory Test Environment Dr Timothy Kamps, National Physical Laboratory
15:25	AI-Enhanced Computational Tribology, Bridging Technology Readiness Levels (TRLs) for Net Zero Transition Dr Mehdi Mohammadpour, Loughborough University
15:55	**Panel Session 2: Creating sustainable future with novel tribological technology**
16:30	IOP Green Networking Reception
1730	Meeting Ends

Abstracts and Speakers

Dr Tom Reddyhoff, Imperial College London

Tom Reddyhoff is a reader in the Department of Mechanical Engineering at Imperial College and a member of the Tribology Group. Tom's background is as a mechanical engineer, though the scope of his research has broadened to include the chemistry and physics of surfaces. Tom's team researches novel ways to improve the performance of sliding interfaces. This requires the development of new measurement techniques used in combination with mathematical modelling.

Using machine learning to help monitor sliding interfaces

It is increasingly important to monitor sliding interfaces within machines, since this is where both energy is lost, and failures occur. Monitoring methods typically involve analysing signals emitted from sliding contacts to obtain friction and wear information. Often these signals result from multiple physical and chemical mechanisms are therefore highly complex. Machine learning models are therefore valuable tools for processing and extracting relevant tribological information. As an example, this talk describes recent research that applies machine learning models to acoustic emission data (i.e., high frequency stress waves caused by micro deformations of component surfaces that propagate through material) from rubbing contacts. Given appropriate signal pre-processing, this approach is shown to yield information, not only friction and wear, but also lubricant composition and degradation.

Dr Julian Stow, University of Huddersfield, Institute of Railway Research

Julian is Associate Director at the Institute of Railway Research at the University of Huddersfield. He has 26 years' experience in the rail industry specialising in rail vehicle dynamics and wheel-rail interface engineering and has led a wide range of projects for the GB rail industry in these areas. He is currently responsible for the delivery of a programme of research work under the Strategic Partnership between RSSB and the University of Huddersfield. Julian is a chartered engineer and a Fellow of the Institution of Mechanical Engineers.

Leaves on the line: simulating low adhesion braking performance of trains

Steel wheels running on steel rails are at the heart of rail transport. They provide one of the major advantages of railways, namely the low rolling resistance which allows movement of large volumes of passengers or freight for modest outlay of energy. The relatively low levels of friction inherent in the wheel-rail interface means that braking performance can become seriously compromised under certain conditions. These typically occur when low levels of moisture are present and other contaminants form a third body layer between the wheel and rail. The addition of leaf material can result in friction coefficients around 0.02, forming very tenacious layers requiring aggressive cleaning to restore sufficient adhesion for safe braking. In addition to the obvious safety issues, managing low adhesion has significant costs for the industry, estimated to be as high as £100M per annum in the UK. The paper describes the development of a simulation model, known as LABRADOR, to predict the braking performance of passenger trains in very low adhesion conditions, and discusses how simulation can be used to improve safety, sustainability and performance.

Dr Gordon Lamb, BP, Advanced Lubricant Products

Gordon Lamb graduated in Chemistry from the University of Birmingham in 1985, and completed a PhD in Polymers, also at Birmingham, in 1989.

He joined Lubrizol Ltd in 1990 in the UK. There he worked in product development and research principally in the area of engine oil lubricants. He has also spent 2 years working for Lubrizol in the US. He joined bp in 2002 taking over as Team Leader of the Heavy Duty Diesel product development team. He was appointed Advisor, Engine Oils in 2004 and Senior Advisor in 2019. Gordon spent 3 years working at the Castrol China Technology Centre in Shanghai. In his role as an Advisor he provides guidance to bp on engine oil development and more recently the implementation of digital solutions intechnology.

He has published and co-authored papers and books on lubrication technology.

Tribology Testing and Data Models

Lubricants are critical to keeping the world moving and Tribology is an essential discipline in understanding how lubricants work in helping to reduce friction and wear of interacting surfaces. Whilst fundamental research in tribology on model systems has played an important role in understanding lubrication, an increasingly important part of the discipline of Tribology for a lubricants company is applying it to understanding fully formulated lubricants. This talk will discuss the benefits of digitising tribology results and bringing it into the cloud where it can be processed and then modelled against formulation composition and properties.

Dr James Ewen, Imperial College London

Dr James P. Ewen is a Royal Academy of Engineering Research Fellow in the Department of Mechanical Engineering at Imperial College London. The topic of my Fellowship is 'Controlling Friction through Molecular Engineering'. The primary focus of my research has been improving the fundamental understanding of the physiochemical processes that occur between moving surfaces to help rationally design lubricants, e-fluids and other formulations with improved performance and sustainability. These activities have the potential to significantly reduce fossil fuel consumption and harmful emissions. His research has been recognised through several awards, including the Wen Shizhu Maple Leaf - Young Scholar Award from the State Key Laboratory of Tribology at Tsinghua University, the Innovation in Tribology Award from the Institute of Physics, and the Tribology Bronze Medal from the Institution of Mechanical Engineers.

Molecular Simulations in Tribology: Towards the Virtual Screening of Lubricants

The development of high-performance lubricants is a critical activity in the pursuit of net-zero. Over the last decade, molecular simulations in tribology have progressed from simple atomic fluids, towards increasingly realistic molecular formulations. The dynamics of large polymer additives, as relevant to viscosity modifier additives, can now be simulated using atomistic or coarse-grained force fields. The range of physicochemical processes that can be studied has also expanded through the introduction of reactive and more recently machine learning force fields for the tribochemistry of antiwear and extreme pressure additives. The accuracy of these simulations has increased to the point where useful predictions can be made regarding the performance of previously untested molecules. This opens the possibility of high-throughput virtual screening for the rational design of new lubricant formulations.

In this talk, I will discuss some potential applications where these virtual screening methods can have a significant impact in the pursuit of net-zero. I will discuss two applications: i) improving the antiwear performance of lubricant additives for aviation through reactive simulations of mechanochemistry and ii) increasing the sustainability of hair care products through coarse-grained simulations. I will also introduce two methods to extend the timescales accessible to molecular simulations to enable direct comparison with experiments: the transient-time correlation function (TTCF) algorithm for studying lubricant rheology at low shear rates and ii) the kinetic Monte Carlo (kMC) technique for simulating tribofilm growth from antiwear additives.

Mr Ryan Manthiri, Shell Global Solutions (US) Inc

Ryan Manthiri, Project Leader in Shell's Global Solutions Technology Group, is a mechanical engineer with an interest in vehicles, engines and the energy sector. He has led diverse technical projects across multiple sectors including Motorsport, Manufacturing, Mining and Oil & Gas. Ryan has a degree in mechanical engineering from the University of KwaZulu-Natal, South Africa.

Digital Transformation in Oil Condition Monitoring (OCM)

In-situ oil condition monitoring (OCM) is an essential requirement of predictive maintenance, especially in applications where timely oil changes are critical. Advances in oil sensing technologies coupled with the advent of big data analytics, has seen the OCM Market shift from a fairly reactive service offering, to a real-time quantitative, predictive and more sustainable solution, enabling better equipment utilization - Efficient machines consume less energy and oil, thus improving overall carbon footprint.

Electrochemical Impedance Spectroscopy (EIS) had been identified as a promising technique to achieve effective and economic OCM. In this study, a few commercial EIS sensors and an EIS rig in a Lab-environment were tested for the effectiveness in the identification of common modes of oil degradation.

Dr Marius Gintalas, Brunel University London, National Structural Integrity Research Centre (NSIRC)

Dr Marius Gintalas obtained his doctoral degree in Mechanical Engineering studying fracture toughness measurement methods under impact load. He worked on crack-tip constrain problems and the development of new wire manufacturing methods as a postdoctoral research associate at Manchester and Cambridge Universities. Marius joined fracture mechanics section at The Welding Institute (TWI) Ltd as a senior project leader after postdoctoral period of five years. In 2020, he returned to academia as a lecturer at Brunel University of London. Recently, collaborating with Southampton University he has successfully delivered two projects on rolling contact fatigue to Rail Standard and Safety Board.

Revealing different crack growth conditions in twin-disc specimen and full-scale rail through finite element analysis

Experimental and numerical investigation of rolling contact fatigue (RCF) and associated crack growth in rails and wheels remain a major concern for railway industry and railway research. There is a need for cost and time efficient small-scale testing approaches capable to replicate full-scale wheel-rail interaction. This would speed up the development of novel rail steel grades with an improved RCF life. Current laboratory-scale experimental studies of RCF mostly relay on twin-disc experiments. However, the difference in crack lengths experimentally observed in full-scale rail components and twin-disc specimens is significant.

The aim of this talk is to present finite element study conducted to investigate crack growth conditions in twin-disc and full-scale wheel-rail models. The first part of the presentation will focus on the development of residual strain filed below the contact surface in both geometries under the same applied contact pressure and slip ratio. In the second part of the talk simulation results revealing the major crack growth differences in twin-disc and rail under equivalent applied RCF loading will be presented and discussed.

Dr Timothy Kamps, National Physical Laboratory

Timothy Kamps is a Tribologist in the Advanced Engineering Materials group at NPL. He is experienced in the design and analysis of laboratory experiments that quantify the friction and wear of lubricated interfaces. Timothy received his MEng & PhD degrees from the University of Southampton. Timothy is currently developing in situ contact and non-contact topography measurement technologies for both unidirectional and reciprocating tribometers. This capability provides high value tribology testing by reducing both the number and duration of tests required to investigate friction and wear phenomena.

Advanced Sensing and Data Processing Using Machine Learning in Laboratory Test Environment

The National Physical Laboratory (NPL) is the UK's National Metrology Institute and is responsible for developing and maintaining the national primary measurement standards as well as developing the metrology capability required to deploy new technologies with organisations as they develop solutions for the Journey to Net Zero. The tribology team working in the Advanced Engineering Materials group at NPL works to apply robust and traceable measurement methods to characterise the friction and wear performance of new materials and lubricants. Experimental methods that have been developed in response to these tribological challenges will be presented with a focus on sensing and data processing.

Dr Mehdi Mohammadpour, Loughborough University

Dr Mohammadpour is associate professor at Loughborough University, leading a team of researchers in the field of powertrain tribology. He is also the founder and CEO of a university spin-off, TriboDENS Ltd. which provides simulation tools and test methods and facilities in the field of tribology.

His academic background is in the field of mechanical engineering, and his research has led to more than 70 journal publications, 10s of conference presentations and invited lectures and 8 successful completion of PhD projects under his supervision. He is member of NAFEMS' steering group and serves as member of the editorial board in several journals.

AI-Enhanced Computational Tribology, Bridging Technology Readiness Levels (TRLs) for Net Zero Transition

Simulation of mechanical contacts help engineers to optimise the combination of geometry, lubricant, material and their system level integration. The aim is to maximise the life of contacts, whilst reducing friction to minimise energy losses. The main barriers in comprehensive simulation of contacts are the complexity of building detailed models and high computational cost, requiring significant computational resources. These barriers may deter engineers from using this crucial simulation for design and optimisation purposes, and instead, rely on physical prototyping (trial and error). Advances in AI technologies offer an opportunity for breaking this barrier by accelerating simulation. Such data-driven method which will be based on a combination of experiment and simulation can enable practical tribological simulations. The method can deliver results in 100s-1000s of times faster.

After design and development of mechanical components containing contacts, such as gears and bearings, they undergo continuous tests to validate the design; and improve it by optimization of lubricant, material, geometry or the system integration. There is always a characterization of the tested surface involved, as part of this continuous process. Characterization includes identifying the nature of the wear and also quantifying that. This process is currently performed by technicians, leading to subjective assessment or mis-identification. An AI-based approach which can receive images of the surface, and identify the type of wear and quantify their severity can also enable a data-driven post-design optimisation.

Abovementioned methods will support a rapid transition towards Net Zero by enabling detailed simulation and characterisation of contacts to reduce the reliance on physical prototyping. This presentation will review the recent efforts in implementing AI-based methods in computational tribology, and will present examples of data-driven simulation and wear characterisation in industrial context

Digital Solutions for Tribology – The Journey to Net Zero

8 November 2024
Institute of Physics, London, UK