

ABSTRACTS

ECOTRIB 2025

28 - 30 July

9th European Conference on Tribology

ETH zürich



SwissTribology



Swiss Tribology

28th July, 2025

Dear Colleagues

It is with great pleasure that I welcome you all to the 9th European Conference on Tribology, Ecotrib 2025. Ecotrib is the biennial meeting organized by the tribology societies of Austria, Italy, Slovenia, and Switzerland. We are however also very pleased to welcome participants from more than 20 countries.

The focus of this conference is on providing young researchers, at PhD and post-doc levels, with an opportunity to present their results to an international audience. In addition, we have presentations from many well-established researchers and our hope is to generate vibrant discussions, leading to new collaborations and innovation in the field of tribology.

We very much appreciate the support of our sponsors: Optimol Instruments, Blaser Swissslube, Oerlikon, Rösler, Alemnis, OTEC, Rtec-Instruments, TriboDens, and Anton Paar. Their support has been a great help in making the conference more affordable for participants.

Also, my heartfelt thanks go out to the co-organisers of the meeting, Josephine Baer, Nicholas Spencer, Emanuel Tack, and Anna Igual Muñoz.

I hope you all enjoy your time in the vibrant and beautiful city of Zurich, visit many interesting presentations and exhibitor stands, and take part in many fruitful discussions on the subject of tribology.

Rowena Crockett
President, Swiss Tribology

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Invited Speakers:



Rosa Espinosa

Dr. Rosa Espinosa has been a Professor at the University of Illinois at Urbana-Champaign (UIUC) since 2013 and holds a joint appointment in the Departments of Materials Science and Engineering and Civil and Environmental Engineering. Her research group focuses on soft materials and interfaces, with particular attention to fundamental aspects of tribology. Since 2016, she has served as a member of the executive committee of the Division of Colloid and Surface Chemistry of the American Chemical Society, where she currently holds the role of Vice-Chair. She is also the Chair of the 2026 Gordon Research Conference on Tribology.



Nuria Espallargas

Nuria Espallargas is a Professor at the Department of Mechanical and Industrial Engineering. She has a MSc in Chemistry from University of Barcelona (Spain) and a PhD in Metallurgy and Materials Engineering from the same university. She has also been the NTNU leader of the Gemini Centre "Tribology" since 2011. Her research interest include surface chemistry and engineering, tribology and tribocorrosion. Lubricants (including environmentally acceptable), and nano-tribology.



Guillermo Enrique Morales-Espejel

Principal Scientist SKF Research and Technology Development, The Netherlands, Chair Professor at LaMCoS, INSA de Lyon, France. Visiting Professor at Imperial College London. PhD in Tribology from the University of Cambridge, U.K., holder of "Habilitation à Diriger des Recherches (INSA-Lyon)", 10 years lecturer in university and more than 25 years of experience in rolling bearings. Author of more than 100 scientific papers and several book chapters. Associated Editor of Tribology Transactions and IMechE Part J. Scientific interests are Modelling of Bearing life, friction, lubrication and surface life.



Ken Nakano

Ken Nakano is a full professor at Yokohama National University. He obtained his doctorate at the University of Tokyo in 1997. After serving as an assistant professor at Saitama University and an associate professor at Yokohama National University, he assumed the current position in 2015. He has been an editor of Tribology Letters since 2024.



Lars Pastewka

Lars Pastewka is a Professor of Simulation in the Department of Microsystems Engineering and Vice Dean of the Faculty of Engineering at the University of Freiburg. His research employs computer simulations at atomic and mesoscopic scales to investigate mechanical processes, with a focus on contact, adhesion, and friction. Prof. Pastewka received his Ph.D. in Physics from the University of Freiburg while working at Fraunhofer IWM. He completed a postdoctoral fellowship at Johns Hopkins University and led a junior research group at the Karlsruhe Institute of Technology before joining the University of Freiburg as a faculty member in 2017. He has been recipient of a Fulbright Fellowship, a Marie Skłodowska-Curie Fellowship, an Emmy-Noether Award and an ERC Starting Grant.



Stefan Eder

Key Researcher at AC2T research GmbH, Section Leader and Lecturer at TU Wien, Austria, where he leads nanoscopic modeling in tribology. PhD in Physics (2012) and habilitation in Computational Materials Tribology (2024) from TU Wien. Visiting researcher at UC Merced and Imperial College London. Author of ~65 peer-reviewed papers and frequent speaker at international conferences. Research focuses on microstructural evolution under tribological load and tribochemical simulations. Active in national and EU-funded projects (e.g., FFG, Horizon 2020), editorial board member of Tribology Letters, and organizer of the Vienna Virtual Materials Tribology Workshop.

Monday, 2025-07-28	HG E7 (346)		HG E5 (255)	
Introduction	8:45-9:00	Chair: Rowena Crockett		
Invited Talks	9:00-9:45	Introduction Guillermo Morales: Surface Life Challenges in Machine Elements		
	9:45-10:30	Ken Nakano: Tribodynamics: Dynamic Nature of Tribosystems		
Coffee	10:30-11:30		10:30-11:30	
Sessions		Chair: Nicholas Spencer		Chair: Michael Pusterhofer
Talk 1	Coatings I 11:30-11:50	Alberto Rota: Ultra-low friction regime of nano-functionalized DLC surface	Liquid Lubrication 11:30-11:50	Gary Nicholas: Measurement of hydrodynamic oil film thickness and pressure from a tilting-pad journal bearing
Talk 2	11:50-12:10	Emanuel Tack: Optimization of diamond-like carbon coatings for gears	11:50-12:10	Alberto Betti: Optimal pad sensor position in a Tilting Pad Journal Bearing
Talk 3	12:10-12:30	Filippo Mangolini: Effect of Alloying Elements on the Tribological Response of Amorphous Carbon Coatings	12:10-12:30	Philippe Kempe: Evolution of Testing Methods for Lubricants and Current Trends with Electrified Tribology
Talk 4	12:30-12:50	Mohammad Alinezhadfar: Tribological Behavior of Novel Zinc/Zinc-Phosphate Composite Coatings	12:30-12:50	Balasubramaniam Vengudusamy: Role of additives and tribofilms on WEC failures
Lunch	12:50-14:00		12:50-14:00	
Sessions		Chair: Daniel M. Mulvihill		Chair: Florian Ausserer
Talk 5	Coatings II 14:00-14:20	Prathima C. Nalam: Designing Low-Friction Interfaces through Surfactant Intercalation within Graphene Nanogaps	Extreme Lubrication I 14:00-14:20	Matthias Freisinger: Assessing Flange Lubricant Performance Under Challenging Conditions in Swiss Metre-Gauge Railways
Talk 6	14:20-14:40	Anna Igual Munoz: Tribological behavior of NiCr self-lubricating laser cladding materials	14:20-14:40	Marco De Stefano: Investigations on tribocorrosion of AISI 316L in marine environment
Talk 7	14:40-15:00	Julien Keraudy: Advanced DLC Coatings by S3p® Technology For Tribological Demanding Applications	14:40-15:00	William Gray: Preliminary Development of Spark Plasma Sintered, Self-Lubricating Metal Matrix Composites for Aircraft Bush Joints
Coffee	15:00-16:00		15:00-16:00	
Sessions		Chair: Wilfred Tysoe		Chair: Rosa Espinosa
Talk 8	Data Analysis and Modelling II 16:00-16:20	Markus Varga: Physics informed machine learning for vibrations forecast in industrial mechanical systems	Boundary Lubricants I 16:00-16:20	Pierre Montmitonnet: Polarity-Dependent Effects of Electrification on Lubricant Additives under Boundary Lubrication
Talk 9	16:20-16:40	Nick Garabedian: Collaborative Intelligence: Redefining Tribology through FAIR Data Modeling and AI	16:20-16:40	Chuan-Chieh Wang: Mechanochemical Coupling of Shear and Compressive Stress in ZDDP Tribofilm Formation
Talk 10	16:40-17:00	Max Marian: AI-Driven Rapid Prediction of Elastohydrodynamically Lubricated Contacts	16:40-17:00	Calixe Bénier: Multi-scale study of the lubricating behaviour of two ionic liquids: [BMIM][PF6] and [BMIM][TFSI]

Ultra-low friction regime of nano-functionalized DLC surface

**Alberto Rota^{1,2,3}, Federico Zanni¹, Andrea Mescola², Guido Paolicelli², Andrea Gerbi³,
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Diamond-like carbon (DLC) is widely used in many industrial sectors for its protective, antiwear and self-lubricant properties, including biological and food applications [1,2]. An ultra-low friction regime was observed in very ideal conditions, i.e. sliding a Si ball on a DLC/SiO₂ substrate functionalized by graphene sheets (GSs) and nanodiamonds (NDs) in inert atmosphere [3]. The ultra-low friction regime was ascribed to the formation of nanoscrolls consisting of a hard diamond core surrounded by a very inert graphene shell.

In the present study a similar approach has been adopted to obtain an ultra-low lubrication regime in a very industrial system, namely DLC deposited on an additively-manufactured substrate functionalized with GSs and NDs at the interface. A very low (<0.05) coefficient of friction has been reached for low loads (1-4 N) and in inert atmosphere, in spite of a relatively high roughness of the surface (0.6 μm). Raman analysis on the worn area of the countersurface reveals the presence of nanoscroll structures. At higher loads or in humid atmosphere the ultra-low friction regime does not appear. All these results indicate that some requirement must be fulfilled for nanoscrolls formation, i.e. dry ambient and low load. In presence of humidity and at high load the wrapping of the GSs around the NDs does not take place, and the functionalization is even detrimental for the abrasive action of the NDs.

References

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- [3] D. Berman, Science, 348 (2015) 1118

Optimization of diamond-like carbon coatings for gears

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The main objective of the project is to increase the efficiency of reduction gears in electric vehicles to increase the range.

In previous research projects such as FVA 393 I & II and FVA 585 I, II & III, it has been shown that functional carbon-based coatings on gear components can have a friction-reducing effect in the lubrication regime of boundary, mixed friction and in the regime of hydrodynamic lubrication. A reduction of the average gear friction coefficient by a maximum of 20% was demonstrated by coating spur gears with DLC (= Diamond Like Carbon). [1] [2] The effect is mainly based on the reduction of fluid friction in the hydrodynamical lubrication regime. In this project work, it is shown how DLC coatings are specifically optimized for the use on gears in the gearbox regarding tribological performance. Since it is hardly possible to carry out tribometer tests on a curved tooth of a helical gear wheel in a model test, a flat specimen is used instead of a single tooth. This flat specimen is placed in a dummy gear and therefore experiences the same geometric shading effect during the coating process as would be the case with a tooth. The flat specimens were specifically adapted to the properties of the real gear components in terms of material, hardness process and roughness, which makes it possible to transfer the results obtained from the model tests to time-consuming and cost-intensive gearbox tests. With the help of SRV tribometer tests on flat specimens, the mechanical-technological performance of DLC coating variants could be determined. The result of the specifically optimized coating architecture and its mechanical-technological properties are high-performance DLC coatings for gears, which offer high wear protection from the gear dedendum to addendum, even in the lubrication regime of boundary lubrication.

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Effect of Alloying Elements on the Tribological Response of Amorphous Carbon Coatings

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Dopants and alloying elements are commonly introduced in amorphous carbon (a-C) materials to tailor their mechanical and tribological properties. While most published studies have focused on doping and/or alloying a-C coatings with metals or metalloids, doping a-C films with rare-earth elements has only recently been explored. Notably, our understanding of the shear-induced structural changes occurring in rare-earth element-containing a-C films is still elusive, even in the absence of any liquid lubricants. Here, the friction response of Eu- and Gd-containing a-C films with low hydrogen content deposited by high-power impulse magnetron sputtering (HiPIMS) on silicon was evaluated in open air and at room temperature. The load-dependent friction measurements indicated that the introduction of Gd ((2.3 ± 0.1) at.%) and Eu ((2.4 ± 0.1) at.%) into the a-C matrix results in a significant reduction of the shear strength of the sliding interfaces ((41 ± 2) MPa for a-C, (16 ± 1) MPa for a-C:Gd_{2.3} at.%, and (11 ± 2) MPa for a-C:Eu_{2.4} at.%). Near-edge X-ray absorption fine structure (NEXAFS) spectromicroscopy experiments provided evidence that no stress-assisted sp³-to-sp² rehybridization of carbon atoms was induced by the sliding process in the near-surface region of undoped a-C, while the amount of sp²-bonded carbon progressively increased in a-C:Gd_{2.3} at.% and a-C:Eu_{2.4} at.% upon increasing the applied normal load in tribological tests. The formation of an sp²-bonded carbon-rich surface layer in a-C:Gd_{2.3} at.% and a-C:Eu_{2.4} at.% films was not only proposed to be the origin for the reduced duration of the running-in period in tribological tests, but was also postulated to induce shear localization within the sp²-carbon rich layer and the transfer film formed on the countersurface, thus decreasing the interfacial shear strength. These findings open the path for the use of Gd- and Eu-containing a-C even under critical conditions for nearly hydrogen-free a-C films (*i.e.*, humid air).

Tribological Behavior of Novel Zinc/Zinc-Phosphate Composite Coatings

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Zinc coatings are renowned for their exceptional corrosion resistance and sacrificial anodic behavior on steel substrates, and are extensively utilized in industry [1]. However, the soft nature of zinc limits its mechanical performance, particularly in terms of hardness and wear resistance [2]. The addition of hard particles during the electrodeposition of zinc can effectively address these limitations. Recent advancements have demonstrated that the inclusion of reinforcing particles such as diamond, Cr_2O_3 , and SiO_2 can significantly improve the structural compactness, mechanical strength, and tribological performance of zinc coatings, significantly expanding their potential applications [1-3].

This study introduces a novel generation of zinc composite coatings, composed of a zinc matrix and zinc phosphate crystals. This composite structure is designed not only to enhance corrosion resistance but also to meet the mechanical demands of wear-intensive applications. Unlike conventional methods that rely on a suspension of prefabricated particles, these composite coatings form directly during the deposition process. The research focuses on evaluating the effects of various fabrication parameters on the composition and structure of the zinc/zinc-phosphate composite coatings. Mechanical and tribological assessments are conducted. The tribological behavior of pure zinc coatings and zinc/zinc-phosphate composite coatings is comparatively evaluated under sliding conditions.

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Designing Low-Friction Interfaces through Surfactant Intercalation within Graphene Nanogaps

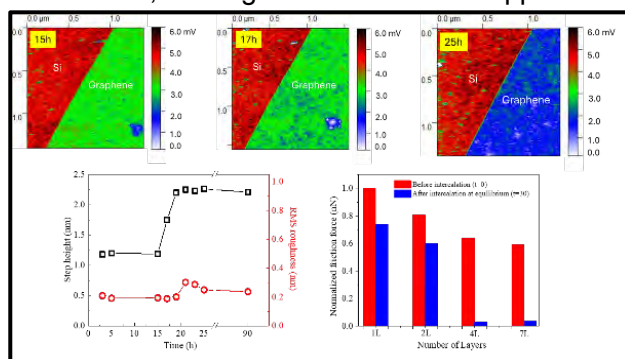
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Two-dimensional (2D) materials have emerged as promising candidates for next-generation solid and liquid lubricants due to their exceptional mechanical properties, atomic thickness, and lamellar structures. When combined with organic molecules or surfactants, these layered materials form intercalated structures within nanoscale confinements, exhibiting unique viscoelastic and tribological behavior. These intercalated interfaces offer an effective molecular-scale strategy to tune friction, making them relevant for applications ranging from MEMS/NEMS to engine lubrication.

In this study, we investigate the role of surfactant intercalation in modulating interfacial friction within graphene-based confinements. Specifically, we combine atomic force microscopy (AFM) and molecular dynamics (MD)



simulations to examine the time-dependent behavior of octylamine molecules confined between single- to few-layer graphene on a silica substrate. Our results reveal a diffusion-driven intercalation process, with a characteristic transition time of ~ 10 hours for octylamines to fully intercalate at graphene–silica and graphene–graphene interfaces. This intercalation leads to a significant reduction in both friction and adhesion compared to non-intercalated systems. Notably, friction reduction is found to be strongly dependent on graphene layer thickness, with intercalated bilayer and few-layer graphene systems exhibiting a more pronounced decrease in friction than their single-layer counterparts. Specifically, an interface with more than four graphene layers observed a nearly order-of-magnitude reduction in the coefficient of friction, achieving superlubricity ($\mu < 0.002$). Further, we systematically evaluate friction hysteresis and solvation forces on these intercalated structures and, through MD simulations, elucidate the molecular origins of their friction and adhesion behavior.

This work highlights how surfactant intercalation, graphene layer thickness, and associated phase transitions within confined 2D architectures can be exploited to design ultra-low friction, lubricous interfaces for advanced engineering applications.

Tribological behavior of NiCr self-lubricating laser cladding materials

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Copper beryllium are hardenable alloys (Cu-Be) widely used in micro-technique applications for combining exceptional mechanical and electrical properties and low friction response. However, their toxicity pushes the scientific community to develop alternative alloys. To do that, lubrication solutions consisting of incorporating solid lubricants into the metallic structure have been proposed. Laser cladding offers the opportunity to obtain different microstructures (i.e. incorporation of hard phases in a ductile matrix or solid lubricants) by changing process parameters, thus allowing for tailoring microstructural and mechanical properties of the resulting material.

In this research work, laser cladded materials were processed using NiCrSiB and NiCrAlY powders with the addition of Ag and MoS₂ solid lubricants. The wear and frictional mechanisms governing the tribological behavior of those NiCr self-lubricating materials were investigated. Tribological tests under dry conditions were carried out by sliding a ruby ball against a CuBePb alloy and the two alternative NiCr alloys containing MoS₂ and Ag. Different loads (above and below the yield strength (YS) of the materials) were applied. Wear volumes were quantified by confocal microscopy while wear morphology and microstructural changes at the surface and subsurface were analyzed by SEM and FIB cross-sections.

Several wear mechanisms were identified including plastic deformation followed by the build-up of a third body. Below the YS of the materials (low load) the NiCrAlY+MoS₂+Ag shows self-lubricating properties with coefficient of friction similar to CuBe and no significant wear was observed. Close to the YS of the materials (high load) the NiCrSiB+MoS₂+Ag shows similar coefficient of friction as CuBePb and in all cases wear was dominated by the formation of a third body.

Advanced DLC Coatings by S3p® Technology For Tribological Demanding Applications

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Diamond-like carbon (DLC) coatings, namely hydrogenated amorphous carbon (a-C:H) coatings deposited by a PECVD process emerged years ago as the ideal solution for applications where component parts are under high loads or subject to extreme friction, wear and contact pressures with other parts. However, there are nowadays many tribological systems, in which the abrasion resistance of a-C:H coatings is at the limit or even insufficient. With its higher hardness, tetrahedral amorphous carbon (ta-C) would provide more abrasion resistance, a longer lifetime and enable a better performance for the related components. However, the state-of-the-art arc-deposited ta-C coatings (filtered or not) are simply too rough for many applications. Possible solutions to improve surface quality are post-finishing methods such as brushing or polishing, which however have a significant impact on the processing costs.

Recently, high power impulse magnetron sputtering (HiPIMS) was reported to be a suitable method to deposit dense hydrogen-free amorphous carbon (a-C) coatings. In this work, we report on the coating growth and properties of smooth and hard carbon coatings produced by the S3p™ (Scalable Pulsed Power Plasma) method in an industrial deposition plant. S3p™ technology enables scalability of the pulse power density and pulse length in a wide range and expands significantly the choice of the deposition parameters and process stability as compared to conventional HiPIMS technology. Smooth and hard hydrogen-free carbon layers were produced using graphite targets in Ar ambient. The thermal stability of the coatings in air and their tribological behavior in dry and lubricated environments were investigated and compared to the results of standard a-C:H and ta-C coatings. Furthermore, the influence of adding a C₂H₂ precursor in an Ar ambient atmosphere on the film properties and S3p™ reactive process was investigated.

Finally, selected applications where carbon coatings deposited by S3p™ outperformed common DLC coatings will be presented.

Physics informed machine learning for vibrations forecast in industrial mechanical systems.

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Vibrations are an inherent phenomenon for most industrial mechanisms and a potential threat of imbalanced forces, increased wear and even disruption of mechanical parts. Monitoring the systems potentially enables early detection of unwanted operating regimes and provide decision time for service planning in advance (predictive maintenance), while machine learning proves to be an efficient approach for detection and short-term forecast of vibration faults. However, the interpretability of processing results and operational robustness for such algorithms is challenging in real-life environments. Physics informed machine learning combines prior physical knowledge with data-driven approaches, enhancing robustness to outliers and providing physical interpretability of processing results. Despite recent success, the application of these techniques to vibrational analysis is still limited. This work enriches this field considering several physically informed machine learning algorithms to forecast vibrational states of a model test rig with axially rotating motion. Several sets of data-driven physical models are designed using direct vibration measurements and are based on versions of ordinary and stochastic differential equations and link the input rotation speed of the axis with the actual three-dimensional vibrations. Several physics-informed artificial neural networks and neural operators are trained with extracted models as additional regularization term and an objective to forecast the future vibrations, given the current ones as an input. The performance of the developed framework trained with and without physics models is compared, showing benefits for processing of intricate data, avoidance of overfit, and stability to outliers. An additional advantage of the physics-informed approach is the reduction of training sets that ease the algorithm preparations in real-life environments. The particularity of the framework presented is a simultaneous use of several physics models that potentially increase the accuracy and flexibility for non-stationary cases. The work shows the maximum forecasting horizon of 20 seconds on the chosen use case and utilizing in average thirty data batches for training. However, the approach is generic, scalable in time and applicable to a broader number of mechanical systems. Data-driven physics models surrogate of this work can be substituted (or used in combination) with models based on real prior physics knowledge, formulated in explicit terms.

Collaborative Intelligence: Redefining Tribology through FAIR Data Modeling and AI

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Digital technologies such as AI and Big Data are now poised to transform tribology through enhanced digitalization and robust collaboration. Yet effectively integrating these tools into scientists' daily workflows remains an unresolved challenge. To harness their full potential, digital systems must grasp the conceptual models that tribologists rely on for critical decisions, ensuring that data is properly structured, contextualized, and verified.

FAIR (Findable, Accessible, Interoperable, and Reusable) data serves as the gateway for machine learning in tribology, especially when FAIR data is produced directly at the tribometer, becoming automatically ready for analysis and modeling. This approach builds on insights from other fields – such as those recognized in the recent Nobel Prize in Chemistry [1] – where strong collaboration on common knowledge bases has yielded remarkable outcomes. Transferring such practices to tribology necessitates reproducibility through uncertainty quantification and traceable calibration. By paying greater attention to the statistical significance of tribological experiments and analysis, we can preserve the context needed to make AI-driven models more reliable.

Moreover, knowledge representation through semantics and knowledge graphs bridges the gap between raw data, domain expertise, and AI-based tools. This offers more than just efficient data management: it facilitates faster, cross-disciplinary discovery. Critically, encoding and citing the origins of this knowledge ensures that ownership and attribution remain clear, an essential safeguard against untraceable web scraping in the AI era.

This presentation will transform these highly abstract concepts into concrete examples of how tribological domain knowledge is modeled via a new FAIR data protocol. We will show an evaluation of the current state of data management in tribology and propose strategies for its improvement. By making tribological data a scalable asset both academic and industrial partners can collaborate more effectively, testing scientific hypotheses with greater speed and depth.

References

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<https://www.nobelprize.org/prizes/chemistry/2024/summary/>

AI-Driven Rapid Prediction of Elastohydrodynamically Lubricated Contacts

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Understanding and predicting the behavior of lubricated tribological contacts is essential for improving the efficiency, durability, and reliability of mechanical systems. However, traditional physics-based modeling of such contacts—particularly in the elastohydrodynamic lubrication (EHL) regime—often involves solving complex, nonlinear equations that demand significant computational resources [1].

Novel, data-driven approach that leverages Artificial Intelligence (AI) and Machine Learning (ML) techniques to enable rapid and reliable prediction of EHL contact behavior [2,3]. This presentation focuses on artificial neural networks (ANNs) trained on large datasets generated from high-fidelity numerical simulations. These networks are capable of learning intricate relationships between input variables—such as material properties, lubricant characteristics, and operational parameters—and key outputs like film thickness, friction, and electrical capacitance [4].

Our results show that ML models not only replicate the behavior of EHL contacts with impressive accuracy, but also do so at a fraction of the computational cost. This opens the door for their integration into higher-level simulations of machine components and full drive systems. As a case study, we demonstrate the predictive capabilities of these models for film thickness, rolling and sliding friction as well as the capacitive behavior of lubricated cylindrical roller bearings. The presentation also discusses the underlying methodology, model training, validation strategies, and the potential of AI to reshape future design workflows in tribology and mechanical engineering.

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Measurement of hydrodynamic oil film thickness and pressure from a tilting-pad journal bearing

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As wind turbines continue to trend upward in size [1, 2] to satiate society's increasingly growing energy demand, manufacturing drivetrain components such as roller bearings to the required precision becomes increasingly challenging. Achieving the necessary tolerances and transporting these components to the installation site presents significant logistical and engineering difficulties [2, 3]. As such, roller bearings are increasingly being phased out in favor of hydrodynamic sliding bearings both for the wind turbine main shaft and gearbox bearings [2-5]. However, little is known about their operational performance (lubrication regime, service life, failure mechanisms). In this work, a multi-sensor measurement suite is developed to measure the hydrodynamic oil film thickness and pressure that forms on the sliding surfaces as the bearing operates. The sensing system comprises of eddy current, ultrasound and pressure transducer. Measurements were taken from a tilting-pad journal bearing test rig subjected to varying loads and rotational speeds.

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Optimal pad sensor position in a Tilting Pad Journal Bearing

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Tilting pad journal bearing performance is strongly affected by film pressure, thickness, temperature, and by variations in pad clearance due to thermomechanical deformations. An accurate characterization of the bearing should include multiple measurements of such quantities. In this work, the optimal positioning of sensors for film pressure, film thickness, pad temperature and pad deformations is discussed. The optimal placement is proposed by targeting the largest absolute value of each signal, considering several operating conditions of a 5-pad flooded rocker pivot bearing [1] within a virtual computational framework (Fig. 1). The proposed measurement setup aims to monitor essential quantities in the bearing while using a limited amount of sensors.

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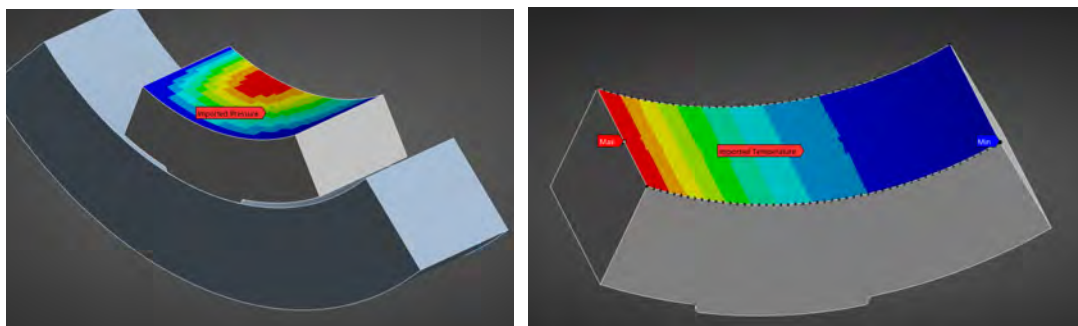


Fig. 1 Pad thermomechanical virtual analysis

Acknowledgments

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Evolution of Testing Methods for Lubricants and Current Trends with Electrified Tribology

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For the characterization of tribological behavior of surfaces with coatings and lubricants, different instrumentation have been developed for specific applications. The physical phenomena occurring may be more complex than a single test and the possibilities to combine different methods show the details of physical effects.

In the field of tribology testing with lubrication, the help of additional methods (ECR and EIS) provides an advanced understanding of the physical phenomena. Measurable electrical quantities in tribometry offer the possibilities to combine impedance measurements with tribology tests showing the influence of variations of electrical properties combined with friction measurements. Transitions of impedance and lubrication regimes can be investigated.

Different testing methods (4-ball, Mini-traction, pin-on-disk) and configurations of tribometers are reviewed and future trends for characterizations are discussed.

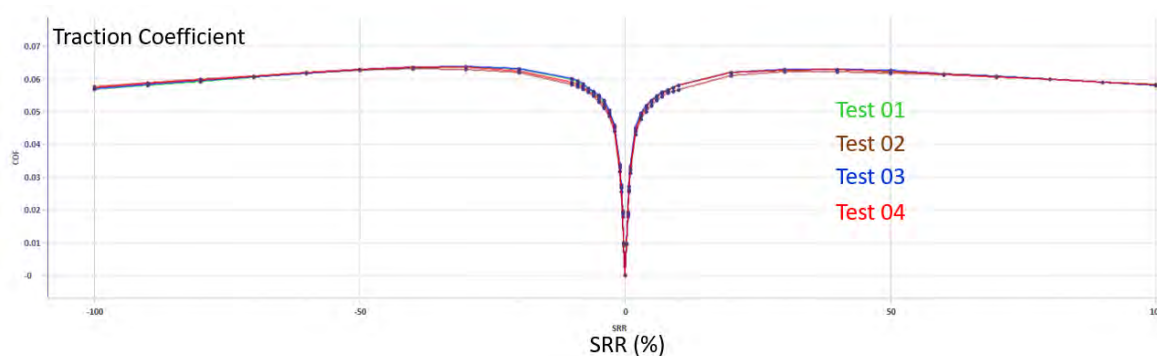


Fig. 1 Traction Curve of reference oil for specific lubricants characterization

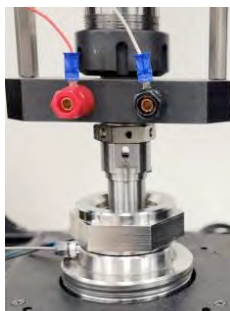


Fig. 2 Advanced setup for electrified tribology tests in presence of lubrication

Role of additives and tribofilms on WEC failures

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White etching crack (WEC) is a subsurface cracking reported to have occurred in many applications including automotive (alternator bearings), wind turbines (WTs) (gearbox bearings), oil and gas refineries (compressors bearings), and many others. Although this problem has been studied extensively over the past many years, there is still a debate on the underlying mechanisms. Additives like ZDDP (branched vs. linear) and overbased calcium sulfonates were studied. This talk will highlight the effects of additive concentration and tribofilm properties on WEC failure.

Assessing Flange Lubricant Performance Under Challenging Conditions in Swiss Metre-Gauge Railways

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Flange lubrication prevents derailment, reduces wear and noise, and improves railway efficiency. This study examines lubricant performance in Swiss metre-gauge railways under sharp curves, steep gradients, varying weather, and high axle loads. Findings help optimize lubrication, cut maintenance costs, and extend component lifespan.

Within the study, different flange lubricants used by metre-gauge railways in Switzerland are investigated in terms of chemical-mechanical properties and tribological performance. Following in-depth chemical analysis, rheometer measurements are conducted to identify dynamic viscosity at various temperatures occurring in the field (-10°C to +60°C). Adhesion of the products is evaluated by a novel tackiness test under varying temperatures and rail surface conditions. With respect to tribological performance, twin disc tests are performed by a high-load twin disc test rig. To picture the challenging conditions in Swiss metre-gauge railways, the parameters include high contact pressures, high slip and extreme environmental conditions.

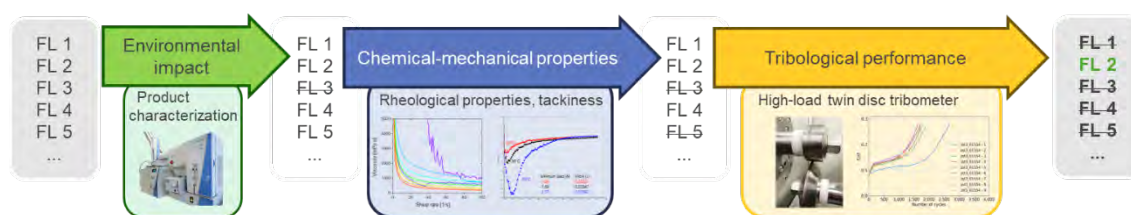


Fig. 1 Stage-Gate-Process to evaluate flange lubricant (FL) for Swiss metre-gauge railway.

The results show that, in addition to the product specifications, notable differences exist among various flange lubricant products. To implement demand-based lubrication in specific environmental conditions, the systematic Stage-Gate Process presented – through time-efficient and cost-effective lab tests – facilitates an efficient pre-screening to identify the optimal flange lubricant for the railway and its route characteristics.

Investigations on tribocorrosion of AISI 316L in marine environment

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Introduction. Tribocorrosion is the discipline involving the simultaneous attack of mechanical and chemical wear [1]. Nowadays it is a diffused phenomenon in several industrial sectors such as transportation, biomedical and marine. The intricate tribochemical processes can act in diverse ways respect of the conditions imposed and tribosystem features. A peculiar scenario is depicted by the positive role played by the synergy known as antagonism that occurs when the total wear rate is reduced due to stability of oxide layer, lubricating action of tribocorrosive products, contact conditions [2].

Materials and methods. The coupling composed of stainless steel 316L and alumina [3] immersed in a solution of 3.8 % NaCl and pH 8.2 simulating artificial seawater was investigated. A linear reciprocating tribometer coupled with two/three electrodes potential was used for the experimental campaign. Electrochemical techniques like open-circuit potential, potentiostatic, potentiodynamic and tribological tests were conducted in accordance with boundary conditions reflecting marine applications. The wear was modelled by synergistic approach as sum of mechanical, chemical and synergy. The first was assessed by Archard's law, the second by Faraday's one and the latter, expressed only by the mechanical wear-induced corrosion, by the difference from the total.

Results and discussion. Key variables like potential, current, friction coefficient, wear were analyzed. Surface analysis, obtained by optical profilometry and high performance software, was even achieved.

Conclusions. Tribocorrosion is a wide and complex field owing to the numerous variables included. The research provided the response of stainless steel immersed in corrosive medium but other experimental trials are surely required as future improvements.

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Preliminary Development of Spark Plasma Sintered, Self-Lubricating Metal Matrix Composites for Aircraft Bush Joints

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This work showcases the preliminary optimisation of an aluminium based metal matrix composite for use in self-lubricated aircraft landing gear bushings. The aluminium matrix is reinforced with silicon carbide to increase material hardness, and tungsten disulfide to act as a solid lubricant, thus enhancing the mechanical and tribological properties respectively.

Spark plasma sintering was used as the fabrication method, with results showing that sinter temperature, temperature ramp rate, dwell time, sinter pressure and the DC pulse on-off time all affect material consolidation to varying levels.

Figure 1 shows coefficient of friction (COF) results from reciprocating ball-on-plane tests under dry sliding conditions. The inclusion of tungsten disulfide reduces COF when compared with 0 wt.% WS_2 , but further improvements are limited at higher dosing due to powder agglomeration, leading to a reduction in relative density. This suggests potential for performance improvement through advanced mixing techniques and optimising the reinforcement dose.

This work sets the foundation for future material blend optimisations, and eventually the tribological assessment of full bush testing.

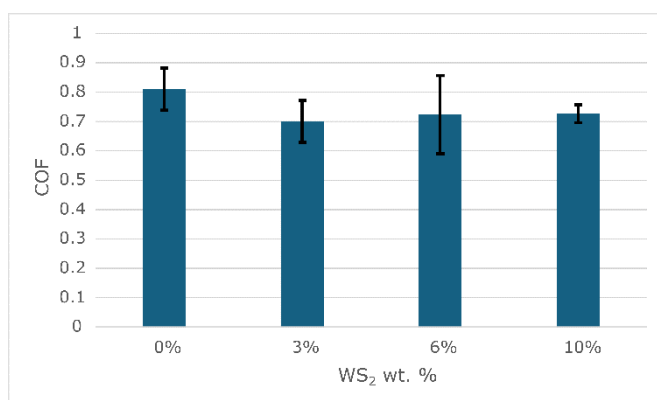


Fig. 1 Coefficient of Friction (COF) relationship with tungsten disulfide (WS_2) concentration

Polarity-Dependent Effects of Electrification on Lubricant Additives under Boundary Lubrication

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While electric vehicles offer environmental benefits, they introduce new challenges in lubricating transmission systems. EV lubricants must deliver effective cooling, resist oxidation, and prevent stray currents from damaging components. Recent studies show that stray currents can accelerate wear through oxidation, potentially intensified by the Joule effect, however, the influence of current polarity remains poorly understood.

In this study, a ball-on-disk tribometer was modified to allow reversal of current direction, enabling investigation of polarity effects under controlled electrified conditions (1–3 A). A low-viscosity EV lubricant was tested to evaluate wear behavior, third-body material transfer, and tribofilm formation (fig.1). Additionally, the impact of lower current levels (0.01–0.5 A) on the performance of individual sulfur-phosphorus based anti-wear (AW) additives was examined. Results indicate that even small electrical currents can significantly reduce additive efficiency, with a critical threshold identified beyond which the tribo-chemistry of AW additives is disrupted, notably by increasing sulfur content and inducing changes in their chemical state.

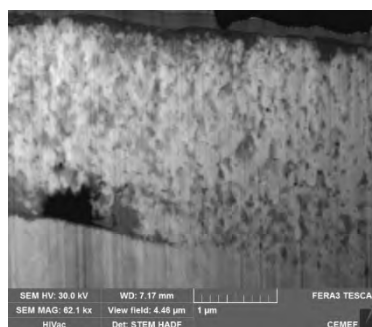


Fig. 1 Scanning Transmission Electron Microscopy (STEM) image of a Focused Ion Beam (FIB) cross-section, showing a ~3 μm thick transfer layer formed after friction testing in boundary conditions with an EV lubricant under a 2 A electric current.

Mechanochemical Coupling of Shear and Compressive Stress in ZDDP Tribofilm Formation

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Zinc dialkyldithiophosphates (ZDDPs) are widely used antiwear additives in engine oils, though their phosphorus and sulfur content raises environmental concerns. A better understanding of their mechanochemical activation and tribofilm formation is needed to support the development of more sustainable alternatives.

This study examines tribofilm growth under independently controlled shear and compressive stresses in full-film EHD contacts using in situ spacer layer imaging. Building on previous results for a secondary ZDDP (methylpent-2-yl, MEP), new tests on a primary ZDDP (2-ethylhexyl, ETH) at fixed shear stress confirmed that compressive stress enhances tribofilm growth. For MEP ZDDP, the effect of compressive stress decreases as applied shear stress increases.

An activation model incorporating a shear-compression cross term was fitted to the data, yielding distinct activation volumes for each stress component. A higher activation volume for shear stress compared to compression suggests that shear is the primary driving force for mechanochemical activation. The positive contribution from both stresses, combined with the observed synergy, indicates that shear and compressive stress also act together on a shared secondary factor that facilitates film formation.

X-ray photoelectron spectroscopy revealed differences in phosphate chain structure in tribofilm formed by primary and secondary ZDDP, and in boundary and full film lubrication regimes. Transmission electron microscopy of FIB-prepared specimens is also being explored to correlate film structure with applied stress conditions.

These findings enhance the mechanistic understanding of ZDDP tribofilm formation and may inform the design of future lubricant additives with improved performance and lower environmental impact.

Multi-scale study of the lubricating behaviour of two ionic liquids: [BMIM][PF₆] and [BMIM][TFSI]

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Ionic liquids (ILs) have garnered significant interest from the tribological community due to their exceptional physico-chemical properties, that include high thermal stability, tuneable viscosity and strong surface adsorption. These properties make them promising candidates for advanced lubrication systems, although their tribological performance depends on the composition, but also on the lubricated-contact characteristics (load, speed, ...).

There is therefore a need to better identify, understand and quantify the phenomena governing friction and lubrication in IL-lubricated systems. Hence, the tribological behaviour of two ILs ([BMIM][PF₆] and [BMIM][TFSI]) was studied across three different dimensional scales (macro-, micro-, and nano-scales). Significant differences were found depending on the testing scale due to the different lubrication regimes exhibited at the different scales: mixed lubrication was identified at the macro-scale, whereas boundary lubrication prevailed at the nano- and micro-scales. To compare the lubrication behaviour in the same regime, the influence of the hydrodynamic film formation was eliminated at the macro-scale. To do so, the frictional force at the macro-scale was extrapolated within the range of velocities probed at nano- and micro-scales. After that, a correlation between friction and load across 8 orders of magnitude was observed. Friction was described using the Bowden & Tabor approach and the influence of plastic deformation and scratching on the tribological performance was highlighted at all scales. Differences between the ILs were attributed to variations in the structure of their adsorbed boundary films and in the exhibited shear strength.

These results emphasized the interplay between lubrication regimes, contact mechanics, and material properties in determining tribological performance across scales, offering insights for advanced lubricant design.

Monday, 2025-07-28	HG E7 (346)			
Introduction	8:45-9:00	Chair: Rowena Crockett		
Invited Talks	9:00-9:45	Introduction Guillermo Morales: Surface Life Challenges in Machine Elements		
	9:45-10:30	Ken Nakano: Tribodynamics: Dynamic Nature of Tribosystems		
Monday, 2025-07-28	HG E33.1 (50)		HG E33.3 (50)	
Coffee	10:30-11:30		10:30-11:30	
Sessions		Chair: Ken Nakano		Chair: Boris Brodmann
Talk 1	Biotribology I 11:30-11:50		Tribological Testing I 11:30-11:50	Jiri Nohava: Biomedical applications of ball-on-disk tribology
Talk 2	11:50-12:10		11:50-12:10	Kartik Pondicherry: Electro-Tribological Testing of Greases
Talk 3	12:10-12:30	Arshad Kalathil Ashik: A fluid-solid coupled solver for cartilage lubrication	12:10-12:30	
Talk 4	12:30-12:50		12:30-12:50	
Lunch	12:50-14:00		12:50-14:00	
Sessions		Chair: Simon Scherrer		Chair: Balasubramaniam Vengudusamy
Talk 5	Biotribology II 14:00-14:20	David Rebenda: Transparent pHEMA Hydrogels: A Model for Cartilage Tribology	Tribological Testing II 14:00-14:20	Thomas Wright: Advancing Tribological Understanding and Performance Optimization of Piezoelectric Inertia Drives
Talk 6	14:20-14:40	Wenxiao Li: Friction of articular cartilage surface lubricated with synovial fluid constituents in contact with glass and hydrogel	14:20-14:40	Andrea Zovko: Characterisation of Near-Surface Thermal Property Gradients in Bearing Steels
Talk 7	14:40-15:00	Vasily Rublev: Bio-Inspired Lubrication: Exploring Fungal Extracts in Water-Based Lubrication	14:40-15:00	Matthias Eifler: Comparability of Measurement Principles: Analyzing Information Content in Tactile and Optical Topography Measurement for Tribological Studies
Coffee	15:00-16:00		15:00-16:00	
Sessions		Chair: Carmine Putignano		Chair: Milena Gleirscher
Talk 8	Biotribology III 16:00-16:20	Samuel S. Gamaniel: Effect of plant-based compounds on mucous boundary layer lubrication during tribological contact	Elastohydrodynamic Lubr. 16:00-16:20	Luciana Nasca: Elasto-Hydrodynamics of Bead-Seat Contacts in Tyres
Talk 9	16:20-16:40	Alejandro Velázquez: Tribological behavior of rice grains: an experimental approach	16:20-16:40	Chiara Cupertino: The impact of spin on elastohydrodynamic contacts for traction: A Theoretical and Experimental Investigation of Ball-Disc Contact
Talk 10	16:40-17:00	Leiming Gao: Lubrication and wear modeling of artificial hip joint replacements with various material combinations	16:40-17:00	Kasra Nosratpour: Application of Artificial Intelligence for Prediction of Elastohydrodynamic Contacts in Machine Elements

A fluid-solid coupled solver for cartilage lubrication

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Articular cartilage is a porous, soft tissue present in the synovial joints that distributes the load and lubricate the joint for smooth body movements. The interstitial fluid within the cartilage and the synovial fluid bath outside the cartilage contribute to its extremely low frictional properties. Modelling cartilage lubrication requires addressing the solid mechanics of the porous-soft tissue and the fluid behaviour inside and outside the cartilage. In this study, we present a solid-fluid coupled model that works at multiple scales to solve for the cartilage mechanics.

We developed two different solvers to solve for the porous solid and fluid parts separately. The solid solver which works at a macro scale computes overall cartilage deformation and interstitial fluid flow based on strain-dependent permeability and differential pore pressure. The fluid solver works at a micro-scale, the roughness of cartilage is incorporated by modifying the Reynolds equation with flow factors. Further, it calculates fluid parameters like pressure and flow based on the deformation profile from the solid solver. Additionally, these two solvers are coupled to interact with each other and exchange results to solve the fluid-solid interaction problem.

To study the effect of different gait cycles, a velocity variation study was conducted. It was observed that the fluid pressure builds up at the inlet of the wedge profile and has an increasing trend with velocity. As a consequence of the fluid pressure, there is more fluid flow into the cartilage at the inlet. At the outlet, we observe fluid out-flow, however, the out-flow is relatively less than the in-flow suggesting positive hydration during loading-induced movements like walking.

The coupled multiscale model provides insights into different cartilage lubrication mechanisms, highlighting the area through which the fluid exchange happens in cartilage. The wedge shape formed due to loading plays a crucial role in fluid pressure built-up which in turn hydrates the cartilage. The trend of increasing cartilage hydration with velocity suggests that walking at increased speeds can hydrate the cartilage more quickly.

Transparent pHEMA Hydrogels: A Model for Cartilage Tribology

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Hydrogels have been investigated as model materials for articular cartilage (AC) replacement in tribological studies or as materials that can potentially replace worn AC in the human body. This study investigates transparent poly(hydroxyethyl methacrylate) (pHEMA) hydrogels as biomimetic AC materials in tribological experiments. A pin-on-plate tribometer was used to assess the frictional performance of pHEMA hydrogels under fully lubricated conditions with a model synovial fluid (SF), while the contact area was observed by fluorescence microscopy to analyse the behaviour of individual SF constituents. pHEMA hydrogels exhibited a coefficient of friction (COF) similar to AC (Fig. 1), with hyaluronic acid (HA) further reducing the COF. In-situ observations revealed HA-phospholipid interactions forming a boundary lubricating layer. These results demonstrate the potential of pHEMA hydrogels for tribological testing and biomimetic material development.

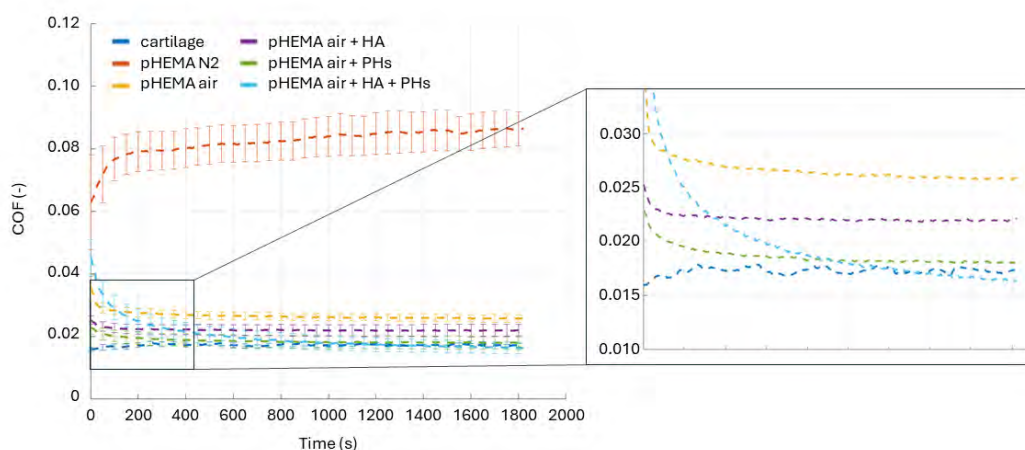


Fig. 1 Friction of pHEMA hydrogels

Acknowledgments

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Friction of articular cartilage surface lubricated with synovial fluid constituents in contact with glass and hydrogel

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Recent studies have reported differing findings on the boundary lubrication properties of synovial fluid (SF) constituents [1,2]. This study examines how different sliding counterfaces affect the frictional behavior of articular cartilage surface lubricated with SF constituents.

Rotational reciprocating tests ($\alpha=30^\circ$) were performed on articular cartilage against a glass probe or a hydrogel-coated probe in a Nano Tribometer (Anton Paar NTR3, Austria). Measurements were conducted over a wide range of sliding velocities (0.05, 0.1, 0.2, 0.5, 1, 2 mm/s) and under extremely low contact loads (5, 20, 100 mN) to minimize contributions from the bulk of the cartilage tissue. To assess the lubrication performance of individual SF components, the contact pair was lubricated with different lubricants containing proteins, hyaluronic acid (HA), and phospholipids.

Results indicated that hydrogel-on-cartilage friction tests showed significantly lower coefficient of friction (COF) than glass-on-cartilage. Proteins reduced COF in glass pairs but not in hydrogels pairs. Hydrogel pairs lubricated with HA-containing solutions mimicked fresh SF behavior, suggesting HA enhances lubrication in hydrogel-based systems.

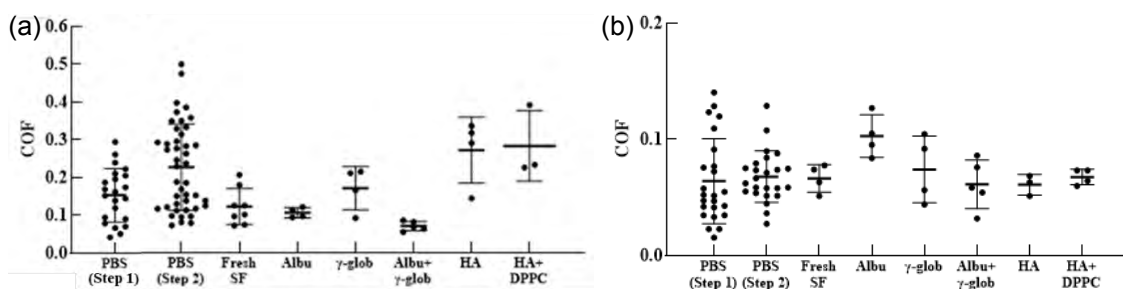


Fig. 1 Friction coefficient of two counterfaces tested at 5 mN, 0.05 mm/s. (a) glass-on-cartilage, (b) hydrogel-on-cartilage.

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Bio-Inspired Lubrication: Exploring Fungal Extracts in Water-Based Lubrication

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The replacement of petroleum-based lubricant ingredients by water-based bio-compatible and eco-friendly fluids has long been a desirable ambition in many engineering applications. However, water on its own is a poor lubricant and additives are required to enhance its tribological performance. Nature offers a wide range of potential solutions to water-based lubrication, examples include mucins, proteins, and polysaccharides. Fungi are an interesting source of polysaccharides that are investigated in this study.

Three popular fungal species: Shiitake (*Lentinula edodes*), Enoki (*Flammulina Velutipes*) and Poria (*Poria cocos*), were used to produce water-based fungal solutions. Lubricants were made from extracts from dried and fresh mushrooms, from powdered mushrooms and from pure lentinan (a β -glucan from Shiitake). A laboratory-scale tribometer (HFRR, PCS Instruments, London, UK) was used to evaluate frictional and wear performance of these solutions, which were compared to baseline values obtained for pure water, hexadecane and bovine calf serum. Stainless steel specimens were employed to enable a focus on friction and wear, without effects of corrosion.

The measured friction was reduced from $\mu = 0.36$ for water to $\mu \approx 0.2$ for the various fungal solutions. Wear results are more complex, in some cases wear was similar to water, but in most cases wear increased. Further analysis showed that the solutions contain non-dissolving sub-micron sized particles, which affect the tribological performance. The wear patch for deionised water shows a ragged, rough surface, whilst the fungal solutions result in a much smoother wear scar. It is hypothesized that the particles in the solutions promote a cutting-like mechanism. By lowering the concentration of the solution and thus reducing the number of particles, the mechanism moved back to a ploughing-type wear. Filtering of larger particles from these low-concentration solutions further reduced the coefficient of friction and resulted in a transition to cutting mode of wear, without a significant increase in wear volume.

These findings indicate that fungal-based lubricants could serve as a promising alternative to traditional lubricants, offering an environmentally friendly, bio-compatible and sustainable approach to tribology.

Effect of plant-based compounds on mucous boundary layer lubrication during tribological contact

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Plant-based proteins offer a higher protein-to-CO₂ emission ratio compared to animal proteins [1]. However, their sensory attributes are often less palatable, largely due to the presence of polyphenols, which can evoke an astringent sensation [2]. Polyphenols interact with salivary proteins, altering lubrication and mouthfeel. This study explores the effect of two plant-based compounds, fava bean protein isolate and tannic acid (TA), on the lubricating properties and structure of mucous boundary layers using a novel methodology combining quartz crystal microbalance with dissipation, atomic force microscopy, tribometry and fluorescence microscopy.

Results revealed that bovine submaxillary mucins (BSM) adsorb onto PDMS, forming a hydrated layer with excellent lubricating properties. Fava binds to BSM and PDMS surfaces, forming a hydrated layer that sustains lubrication. In contrast, tannic acid on BSM causes mucin aggregation, destabilizing the adsorbed layer and impairing the mucins' ability to bind onto PDMS. Shear stresses during sliding of a PDMS probe on the destabilized layer results in a visible damage scar indicating boundary layer removal. This study provides insights into the molecular-level mechanisms influencing oral lubrication, emphasizing the importance of tribological assessment in developing polyphenol-rich plant-based foods.

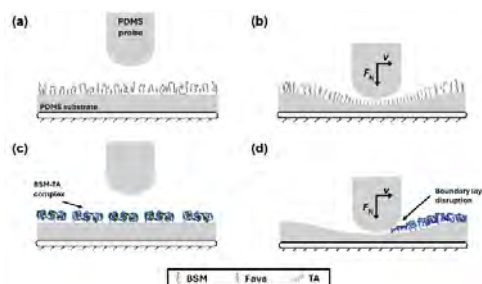


Fig. 1: Schematic illustrating (a) Fava-BSM interaction, (b) mechanical stress effects from a sliding PDMS probe, (c) TA-BSM complexation, and (d) boundary layer removal on PDMS.

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Tribological behavior of rice grains: an experimental approach

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Brown rice grains are known to be formed by a layered microstructure consisting of the endosperm, which is the white interior of the rice kernel, covered by the bran. The specific mechanical properties of the constituents of brown rice grains not only strongly depend on the type of grain but also on their moisture content, the aging of the grains, treatments like parboiling or others. Those mechanical properties could play a relevant role during the steps of rice processing specially in those involving abrasion phenomena. It is, therefore, of importance to develop characterization methodologies allowing for quantifying the mechanical properties of the different grain rice components together with their tribological behavior.

In this research work, ad-hoc characterization methodologies to measure mechanical properties (elastic modulus and hardness) of rice endosperm and its bran will be described. Furthermore, tailored tribological experiments (sliding) allowing for monitoring the frictional force between grain/grain contact will be shown. The experimental observation protocol to describe the initial and final (after the tribological tests) grain morphology will be also detailed. The whole methodology will be applied to assess the effect of moisture content of rice grains on their mechanical and tribological behavior.

The results show that the young's modulus and hardness decrease with increasing moisture for the endosperm, while bran has a considerably lower hardness and young's modulus than the endosperm. The coefficient of friction of the grain/grain contacts lies between 0.05 and 0.2 independently of grain orientation, load and moisture content. The grain surfaces at the end of the sliding experiments showed local worn surfaces only affecting the bran layer.

Lubrication and wear modeling of artificial hip joint replacements with various material combinations

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Total hip joint replacement (THR) is a widely used medical device to restore mobility and alleviate pain in patients with hip joint degeneration. Understanding the tribological behaviour of THR components is critical for improving their performance and longevity. Numerical simulations, particularly in lubrication and wear modelling, offer valuable insights into the in vivo behaviour of hip implants under real-life conditions.

This study presents a comprehensive numerical analysis of elastohydrodynamic lubrication (EHL) in THR, integrating structural deformation effects within the thin-film lubrication approximation theory. The model accounts for major material combinations, including metal (or ceramic) on polyethylene, metal (or ceramic) on polyether ether ketone (PEEK), and ceramic-on-ceramic bearings. The range of Young's modulus for the soft materials spans from 660 MPa to 3 GPa. The governing equations are solved using the finite difference method via in-house programming. Loading conditions are based on ISO 14242 gait cycles to ensure clinically relevant simulations.

The results provide detailed distributions of hydrodynamic pressure and lubricant film thickness across the bearing surfaces, as well as the accumulated wear. Furthermore, the deformation coefficient matrix, one of the most challenging aspects of THR lubrication modelling, will be made available as a database for further research applications.

This work contributes to the development of a robust simulation platform for evaluating the performance of hip implant designs under diverse material combinations and loading conditions, ultimately aiding in the design of more durable and reliable prosthetic joints.

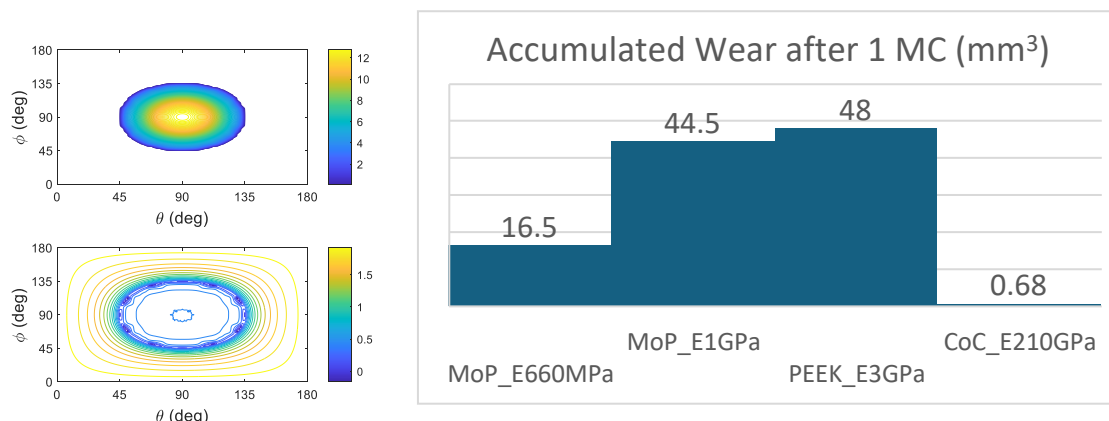


Fig. 1 a) Pressure and film thickness contour at max. loading (MoP); b) Wear volume at 1MC

Biomedical applications of ball-on-disk tribology

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Many biomedical applications require careful determination of frictional properties. They range from the most obvious ones such as articular joints where the coefficient of friction must be kept low in order to allow easy movement on legs and arms to more advanced and less obvious such as catheters which should slide easily into human blood circuit. Friction is however also important when inserting an implant into the bone to ensure the slowest motions and fast osseointegration in the post-operation period. Many of these tribological properties can relatively well be simulated by a ball-on-disk or pin-on-disk tribometer – provided that the real conditions are known. If they are not precisely known, then a meaningful estimation must be made. In this presentation we'll show several examples of measurements of frictional properties of hip and knee joint replacement and catheters. The measurements were requested from biomedical experts interested in comparison of several types of hip and knee joint replacement. The tribotest parameters were known or reasonably well estimated beforehand and could easily be simulated by a pin-on-disk tribometer. We could investigate a large number of test conditions (sliding speed, pressure, material, surface roughness) relevant for the real application. The outcomes obtained on measurements of coefficient of friction (CoF) on the hip implant shaft against bone provided a solid basis for finite element modeling of the stability of bone-implant interface in the post-operation period [1,2]. The second case study focused on coated knee implants and the besides measuring CoF of various types of molybdenum-release preventing coatings in physiologically relevant conditions the adhesion and hardness of the coatings was measured. This provided a complete picture of the mechanical properties of TiN, TiNbN and ZrN coatings on titanium and cobalt-chromium knee implants against UHMWPE. We have shown that the protective coatings have the same or lower CoF than their uncoated counterparts while having higher hardness and sufficiently high adhesion [3]. Finally, we investigated frictional and mechanical properties of coated catheters. Despite not mimicking well the real-life conditions (sliding in air), we were able to differentiate the three different types of catheters, each with different surface treatment. The tribological tests, together with nanoindentation and nanoscratch tests allowed to select the catheter with the lowest CoF and provided insights into the adhesion and elastic modulus of the catheter's surface coatings.

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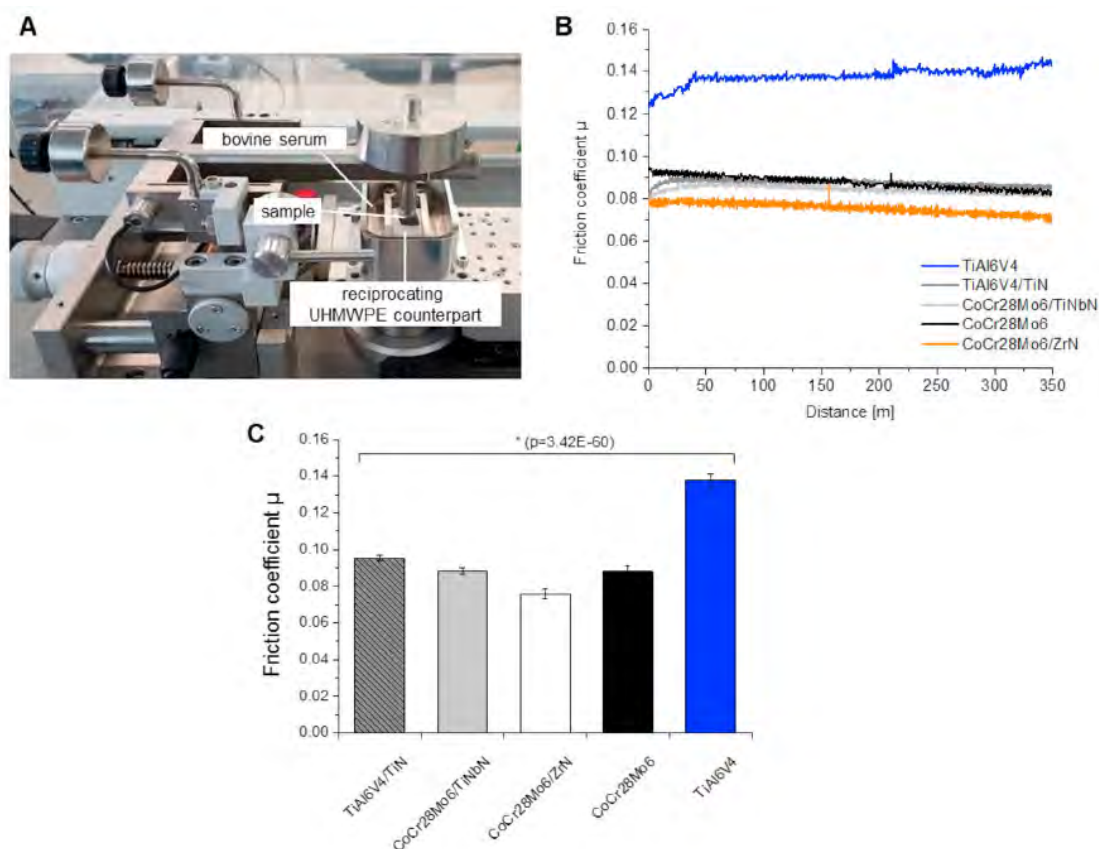


Fig. 1 (A) Pin-on-disk setup for CoF measurement of coated knee implant versus UHMWPE counterbody in bovine serum, (B) CoF as a function of sliding distance of the coated and uncoated knee implants, (C) comparison of average CoF of the tested implants.

Electro-Tribological Testing of Greases

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The viscoelastic nature of greases is crucial to their effectiveness as lubricants, especially in applications where conventional oils are unsuitable. In addition to their rheological behavior, their performance is significantly influenced by tribological characteristics such as friction and wear. With the rapid global growth of electric and hybrid vehicles (EVs), there is increasing interest in exploring the electrical properties of greases to enhance their performance.

In the present study, the authors introduce a novel testing methodology to examine the electro-tribological behavior of lubricants and greases under dynamic conditions. Experiments were conducted using an MCR Tribometer equipped with both ball-on-three-plates and ball-bearing configurations. Extended Stribeck curves, illustrating the frictional response of the tribosystem across sliding speeds spanning eight orders of magnitude, were generated. These tests provide insights into how the electrical characteristics of the tribosystem vary with sliding speed, along with transitions between different lubrication regimes. Additionally, voltage ramp tests were performed to determine the breakdown voltage of the greased tribosystem at various sliding velocities. The influence of temperature on the system's electrical properties was also analyzed. This comprehensive investigation enables the mapping of electro-tribological properties of greases and allows for their correlation with advanced surface characterization, contributing to a deeper understanding of the overall system behavior.

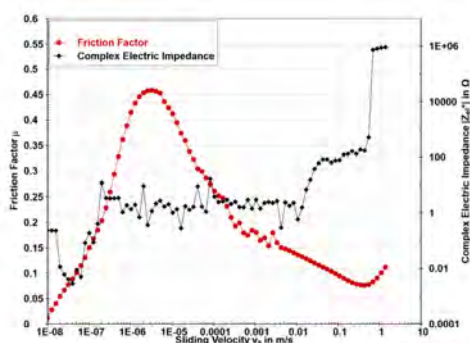


Fig. 1 Figure depicting the frictional response of a grease-lubricated bearing as a function of the sliding velocity, along with the corresponding complex electric impedance.

Advancing Tribological Understanding and Performance Optimization of Piezoelectric Inertia Drives

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Piezoelectric inertia drives (BIX) offer compact and precise motion control, yet their tribological dynamics remain only partially understood. This work aims to deepen the understanding of the fundamental mechanisms governing their operation and to establish a systematic approach for evaluating material performance in these systems. The current design features ceramic-ceramic contact with a hemispherical tip against a flat runner, but alternative materials and surface structuring strategies are being explored to optimize performance.

A key focus is to reassess the prevailing hypothesis that stick-slip behavior, modulated by sliding speed, dictates the directional movement of the system—an assumption now under scrutiny based on recent experimental findings. Furthermore, the study seeks to develop a robust test methodology that enables systematic analysis of new material and surface concepts. By integrating these insights into prototype development, the effectiveness of both the proposed materials and the methodological framework will be validated.

The present study presents initial tribological testing results (Figure 1a) and motion dynamics measurements of the benchmark system (Figure 1b), offering a foundation for further optimization.

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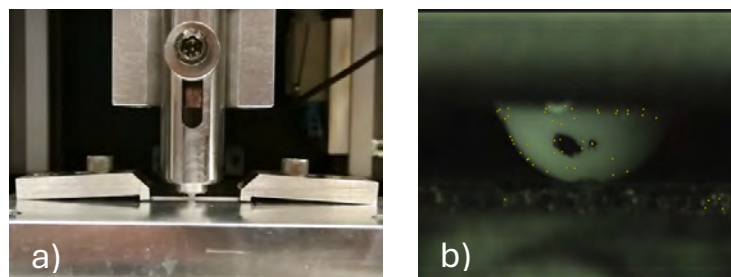


Fig. 1 (a) Initial tribological test set-up, (b) motion dynamics measurements of the benchmark system.

Characterisation of Near-Surface Thermal Property Gradients in Bearing Steels

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Lubricant performance is strongly affected by contact temperature. However, due to lubricant films being thin and contributing relatively little thermal mass, heat transfer in contact is often dominated by the thermal properties of the solids. Previous investigations using Thermoreflectance (TR) thermometry showed [1] that thermal conductivity of the near-surface zone in AISI 52100 is lower than thermal conductivity obtained using bulk-sensitive thermometry like Laser Flash Apparatus (LFA). The disparity between the two values correlates to observed heterogeneity in near-surface microstructure that develops in bearing steels during machining and finishing processes [2]. The variation and impact on thermal properties appears to depend on steel composition, heat treatment, and machining of the specific component.

Analysis of TR data is underpinned by the analytical solution for temperature rise in a semi-infinite solid subject to periodic heat flux, which is ultimately sensitive to sample thermal diffusivity. For a selection of popular bearing steels with different compositions and heat treatments, multi-modal TR is used to simultaneously extract heat capacity and thermal conductivity of near-surface excitation volume [3]. Furthermore, the relationship between heat flux modulation frequency and depth of excitation volume is used to investigate homogeneity in thermal properties of the near-surface zone. Finally, efficiency of different TR modes is compared in terms of applicability to solids relevant to tribology.

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Comparability of Measurement Principles: Analyzing Information Content in Tactile and Optical Topography Measurement for Tribological Studies

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For characterizing the relevant surface structures for tribological processes, there are various measurement techniques of tactile and optical measurement. The unique features of various measurement methods, including tactile profilometers, scattering light sensors, white light interferometers, and confocal microscopy or focus variation are presented, and possible artefacts and deviations specific to the measuring principle are analyzed. The comparability and differences in the informational content provided by each method are discussed, highlighting how these techniques can be combined with each other by offering complementary information. Optical measurements can offer different results than tactile measurements and the comparability of the two approaches can be limited for certain surface features. Additionally, angular parameters can be acquired resulting in a different representation of the surface topography. As a result complementary parameters for process monitoring can be established for both the height and angular distribution. Through correlation studies, it has been shown that height distribution parameters and angle distribution parameters complement each other effectively [1]. For a holistic view, it is often beneficial to consider both perspectives. Our findings suggest that the integration of different measurement methods can enhance the overall understanding of tribological processes by providing a more comprehensive dataset. This approach not only improves the accuracy of the measurements but also offers a more robust analysis of the tribological properties under investigation. We demonstrate this with the example of cylinder liner surfaces that are described in a phase-space representation.

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Elasto-Hydrodynamics of Bead-Seat Contacts in Tyres

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This research deals with the dynamics of the tyre bead-rim system under squeeze contact conditions, employing a combined theoretical, numerical and experimental framework. This type of contact is pivotal not only in the design and manufacturing processes of tyres but also in fine-tuning their performance in real-world vehicle applications. The role of lubricant in tyre mounting is essential, as it temporarily reduces friction between the rubber bead and the metal rim, which in turn improves the durability and longevity of the tyre.

To fully capture the intricacies of this phenomenon, it's necessary to merge the mechanical behavior of the elastic composite material with the fluid dynamics governing the lubricant [1], achieved through the integration of finite difference methods for fluid dynamics with finite element analysis (FEM). The squeeze film method enables the study of time-dependent behaviors, where flow squeeze and elastic deformation processes converge, influencing pressure distributions and film thicknesses over time [2].

This paper also introduces a new approach, through the reduced stiffness method, which minimises data complexity, optimises the research process and significantly reduce the time needed for analysis. Critical parameters such as the thickness and collapse of the lubricant film will serve as the primary indicators for modeling and predicting the behavior of the entire system, with a direct impact on tyre performance both immediately after installation and as it undergoes wear. In addition, experimental results from various test campaigns will be shared. These results not only validate the innovative approach but also provide real-world evidence that supports the theoretical models, offering valuable insights into the squeeze phenomenon and its implications for tyre design and performance enhancement.

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The impact of spin on elastohydrodynamic contacts for traction: A Theoretical and Experimental Investigation of Ball-Disc Contact

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Existing Mini-Traction Machine (MTM) studies on ball-disc wear and traction overlook spin losses, a critical omission for applications like traction drives and continuously variable planetary transmissions [1] where spin significantly reduces efficiency.

The main objective of the work is to evaluate the traction coefficient at the contact, exploiting the principles of the elastohydrodynamic theory of lubrication (EHL), thus simulating the behavior of the system. The theoretical evaluation [2] is characterized by an in-depth analytical approach of the ball-disc contact.

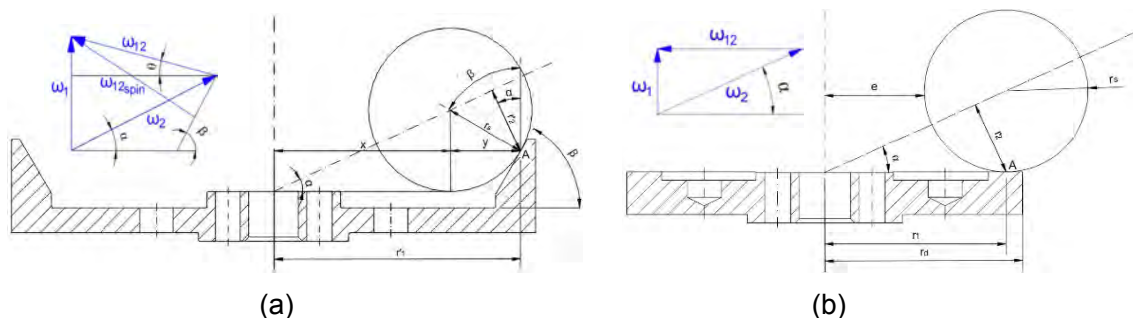


Figure1: Geometry of the MTM specimen operating (a) with spin and (b) without spin.

Furthermore, controlled spin was introduced into a modified MTM test using conical counter-surfaces (0° - 8°), allowing for experimental validation of the model and traction coefficient measurement across five spin levels.

The findings underscore the negative effect of spin on overall performance, highlighting the need to account for this factor in optimizing tribological efficiency in such systems.

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Application of Artificial Intelligence for Prediction of Elastohydrodynamic Contacts in Machine Elements

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The application of analytical and numerical solutions in tribology, such as those predicting lubricant film thickness or friction in EHL contacts have become standard approach in the design of machine elements (e.g. bearing and gears). The numerical approach has always faced high computational time and analytical equations (e.g. extrapolated film thickness equations) have lacked accuracy. With the technological advancement in artificial intelligence and machine learning, a much faster solution (up to 3 orders of magnitude) can be achieved with the accuracy of numerical methods. Such method had been presented in [1], where machine learning was used to predict friction and central film thickness for gears and bearings (**Fig. 1**). However, the abovementioned work was only capable of predicting central value of the film thickness, hence its application for detailed analysis such as shear stress or sub-surface stress field, which depend on localized film thickness and pressure features was limited. In this study, further developed artificial neural network (ANN) is presented, capable of obtaining detailed pressure and film thickness distributions in EHL contacts. Their applicability for bearing and gear design is presented for gear and bearing applications. The ANN model is trained for a 200 nodes computational domain. It consists of 3 hidden layers with 14 neurons each with a ratio of 70/15/15 percent of the data for training, validation and testing respectively.

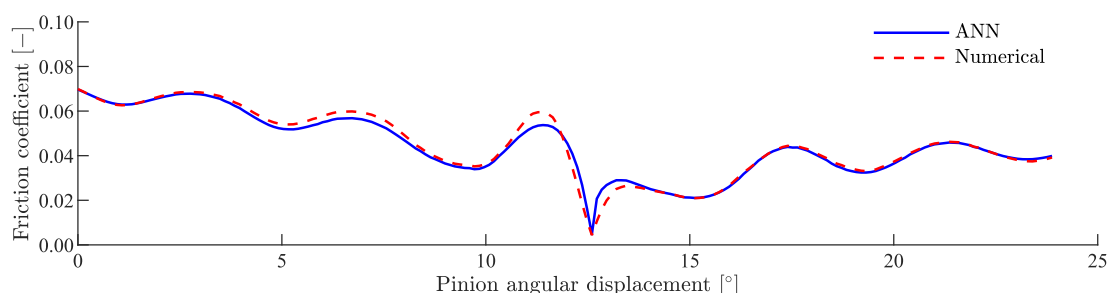


Fig. 1 Friction prediction using ANN vs. numerical approach for a gear meshing cycle [1]

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Monday, 2025-07-28		HG E7 (346)		
Introduction	8:45-9:00	Chair: Rowena Crockett		
Invited Talks	9:00-9:45	Introduction Guillermo Morales: Surface Life Challenges in Machine Elements		
	9:45-10:30	Ken Nakano: Tribodynamics: Dynamic Nature of Tribosystems		
Monday, 2025-07-28		HG E33.5 (40)	HG F 26.3 (46)	
Coffee		10:30-11:30	10:30-11:30	
Sessions	SSLiP: Special Session	Chair: TBA (SSLiP)	Data Analysis and Modelling I	Chair: Michele Santeramo
Talk 1	11:30-11:50	Graham L. W. Cross/A.D. Sinnott: Patterned Surface Contact for Macro Scale Engineering Superlubricity	11:30-11:50	Jin Wang: Pinning versus Lubricity at Moiré Crystalline Interfaces
Talk 2	11:50-12:10	PM Zubieta-Laborde: PyC in all its forms: Towards superlubricity	11:50-12:10	Stefan Peeters: Deriving constitutive laws for slip using molecular dynamics
Talk 3	12:10-12:30	A.K. Gupta: Revealing the role of structure in tribocolloid lubricants to achieve superlubricity	12:10-12:30	Mostafa Gargourimotlagh: Tribological characterization and numerical simulation of semi-solid lubricant in mixed lubrication regime
Talk 4	12:30-12:50	Viet Hung Ho: Patterned Surface Contact for Macro Scale Engineering Superlubricity	12:30-12:50	Oussama Cherguy: Machine learning algorithms for prediction of dry friction coefficient on DLC coatings
Lunch		12:50-14:00	12:50-14:00	
Sessions	SSLiP: Special Session	Chair: TBA (SSLiP)	Industrial, Automotive and Manufacturing I	Chair: Charlotte Spies
Talk 5	14:00-14:20	Ahmed Uluca: Tribomechanical investigation of single micro asperities across-scales by a 2D indenter	14:00-14:20	Yurii Tsybrii: Effects of the composition of train brake friction materials on the emission and properties of wear particles
Talk 6	14:20-14:40	PM Zubieta-Laborde: Green Lubrication via Pharmacopeia-Derived Molecules in Glycerol: Toward Sustainable Superlubricity	14:20-14:40	Olaf Grutza: Temperature management in radial-shaft-seal contacts using additively manufactured porous shafts
Talk 7	14:40-15:00	Viet Hung Ho: A Theoretical Study on Friction of Macroscale Patterned Surfaces: Implications for Structural Superlubricity	14:40-15:00	Lucija Coga: Influence of temperature on tribological properties of different thermoset/thermoset material pairs under water lubrication for pump applications
Coffee		15:00-16:00	15:00-16:00	
Sessions			Industrial, Automotive and Manufacturing II	Chair: Raphael Scharf
Talk 8	16:00-16:20		16:00-16:20	Francesco Amodio: Test Bench for Real-Time Estimation of Soil Parameters via the Locomotion Unit's Proprioceptive Sensors
Talk 9	16:20-16:40		16:20-16:40	N. V. Venkataraman: Use of micro-Raman spectroscopy in tribological studies: The case of metal nitride coated tungsten carbide pins dry sliding on steel discs
Talk 10	16:40-17:00		16:40-17:00	Prateek Pathak: Self-healing Transparent Super Slippery Surfaces for Drag-Reduction and Anti-Icing Applications

Patterned Surface Contact for Macro Scale Engineering Superlubricity

**A.D. Sinnott¹, Ahmed Uluca¹, Paul-Marie Zubieta-Laborde², Viet Hung Ho³, Zahra Gholamvand¹, Melisa Gianetti³, Astrid de Win³, Marie-Isabel De Barros Bouchet²,
Graham L.W. Cross¹**

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Engineering superlubricity, defined as having a coefficient of friction below 0.01, can be achieved under specific circumstances such as mismatched atomic lattices in two dimensional materials[1] and incommensurate contact in patterned surfaces[2]. The EIC project SSLiP aims to bring this concept to the macro scale, enabling real world applications.

Scale-up is being realized by a combination of concepts including the use of tribocolloids (micron scale colloidal particles with tribological coatings), micropatterned surfaces to reduce contact area, and surface coatings of 2D materials and carrier fluid. These are predicated on ideas around creating a dynamic network of superlubricious contacts that manages total friction through understanding of dissipation in granular systems.

We present a variety of fabrication methodologies including colloidal directed assembly and photolithography to create patterned countersurfaces. Testing is performed with macroscale contact geometries, as well as microscale tribometer contacts to understand underlying mechanisms, and is supported by numerical simulation. Baseline ball and flat on flat friction coefficients below 0.01 have been maintained over thousands of cycles for sub-millimeter contact geometries. We discuss the effect of patterned surface geometries on our ability to extend these results to larger scales.

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PyC in all its forms: Towards superlubricity

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Achieving superlubricity, i.e. friction coefficient below 1%, in a sustainable way under severe sliding and sliding/rolling operating conditions is considered as the graal in tribology field¹. The severe conditions can be obtained, among others, by a low velocity of the relative motion between the contacting surfaces or by high pressure of contact. Therefore, the goal of this work is the development of new tribo-systems capable of shifting the Stribeck curve towards more severe conditions and lower friction level. To reach such an objective the technological solution proposed is based on two contributions: the static topography and the dynamic topography. The static topography consists of texturing the contacting surfaces of the two counterparts (that are coated with amorphous carbon or not). And the dynamic topography consists of using an appropriate lubricant with micro-colloidal particles or 2D materials such as hypericin, MoS₂, pyrolytic carbon etc. The present work will focus on the impact of pyrolytic carbon in every case of the static and dynamic topography.

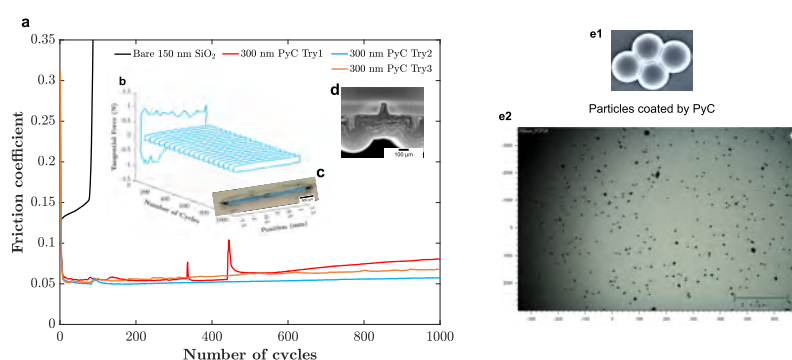


Figure 1 (a) Friction curves of a 300 nm PyC coating on a 150 nm SiO₂-wafer. (b) Tribo-loops associated to the PyC friction behavior. (c) Optical image of the flat wafer after experiment. (d) SEM image of the structure of PyC. (e1) SEM image of SiO₂ particles coated by PyC (tribocolloids). (e2) In-situ image of a glycerol lubricated friction experiment with tribocolloids.

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Revealing the role of structure in tribocolloid lubricants to achieve superlubricity.

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Structural Superlubricity is a mechanism of ultralow friction which occurs due to atomic lattice misfit between clean, flat, rigid crystalline surfaces achievable with 2D materials. So far, it has been mostly a curiosity, observed between idealized surfaces. In this project, we explore upscaling of this phenomenon using tribocolloidal particles coated with 2D materials such as graphene and MoS₂. Using these coated granular particles, we investigate the resulting friction reduction at the macroscale as a function of parameters such as particle size, polydispersity, solvent and boundary conditions. We elucidate the tribocolloid structure under sliding by direct imaging and simulations to obtain insight into the friction behaviour and optimize friction reduction. Experimentally, we combine testing devices with confocal microscopy to visualize the particle structure in three dimensions and real time. We find very low friction coefficient with tribocolloids suspended in glycerol compared to and the bare silica particles suspended in glycerol.

Combined with simulation results from our collaborators, we obtain insight into the role of surface roughness, solvent and normal load in the formation of tribocolloid structures mediating the resulting macroscopic friction reduction.

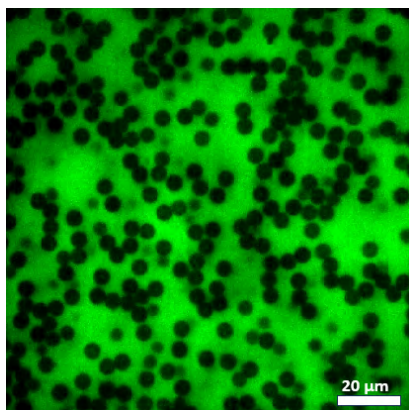


Fig. 1 Tribocolloid suspended in 80% glycerol

Tribomechanical investigation of single micro asperities across-scales by a 2D indenter

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Macroscale superlubricity and friction control have become a significant topic with the advancement of surface engineering and materials research [1, 2]. However, most of the tribomechanical research has been realized with traditional macroscale tribometers with support from the nanoscale investigations by simulations and scanning probe techniques while the intermediate regime at the microscale has been left uncontrolled/measured. Here we have developed experimental methods for investigating single micro asperity under harsh tribological conditions by configuring a two-dimensional (2D) nanoindenter as a tribometer to illuminate this regime.

The employed 2D nanoindenter consists of 2 coupled 50 mN maximum load capacity indenter actuators supported with oscillation analysis capacity with 2 separate lock-in amplifiers for especially stiffness detection in vertical and lateral directions. Using a nanoindenter setup for tribomechanical analysis allows us to start from local shearing and static friction analysis and investigate the sliding friction for speeds $\mu\text{m/s}$ to mm/s for a variety of contact pairs and pressure regimes (MPa to GPa by changing the contact curvature). We will demonstrate our testing capacity with two examples in this presentation: single atomic layer lubrication for mesoscale diamond-silicon oxide contacts for local shearing at ~ 1 GPa maximum Hertzian normal pressure, and glycerol-assisted polishing of silicon oxide-steel contacts under ~ 250 MPa Hertzian normal pressure with hydrodynamic lift effect at mm/s contact speed for single microcontact. Along with these example investigations, we will discuss the significance of the microscale experimental analysis for especially scale-up efforts of superlubricity and friction control by microscale patterning/geometry by pressure/shear optimization.

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Green Lubrication via Pharmacopeia-Derived Molecules in Glycerol: Toward Sustainable Superlubricity

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Achieving sustainable superlubricity (friction coefficient <1%) under severe sliding or sliding/rolling conditions is considered the ultimate goal in tribology. In lubricated systems, such harsh conditions arise from low sliding speeds or high contact pressures. The SSLiP project aims to develop new tribo-systems capable of shifting the Stribeck curve toward more severe regimes while lowering friction. The proposed solution relies on two key elements: static and dynamic topography. Static topography involves surface texturing of the contacting components (coated or uncoated with amorphous carbon), while dynamic topography uses tailored lubricants containing micro-colloidal particles or 2D compounds—particularly eco-friendly, pharmacopeia-derived molecules like hypericin and chrysin. Friction coefficients are measured using various tribometers. Notably, some 2D compounds have rapidly achieved superlubricity under glycerol-lubricated conditions with steel/SiO₂ tribopairs, without noticeable wear (Figure 1). To understand the mechanisms and scalability, worn surfaces are analyzed via spectroscopy and nanoscale imaging, revealing these molecules' ability to maintain low friction under severe boundary conditions and near-zero sliding speeds, where lubricant starvation typically occurs.

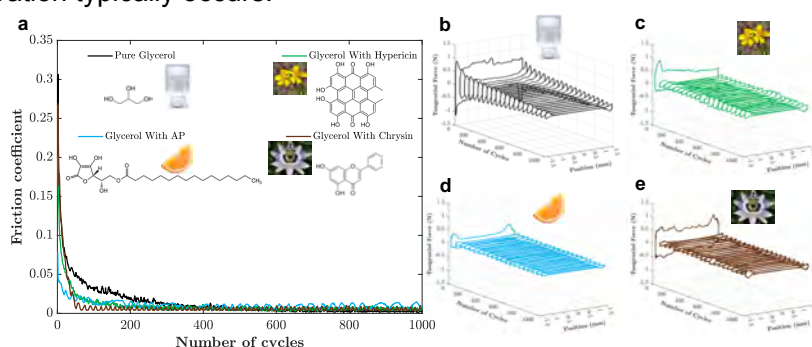


Figure 1 (a) Friction behaviors of the different additives in glycerol. (b) Tribo-loops of pure glycerol. (c) Tribo-loops of Hypericin in glycerol. (d) Tribo-loops of ascorbic acid-6-palmitate in glycerol. (e) Tribo-loops of Chrysin in glycerol.

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A Theoretical Study on Friction of Macroscale Patterned Surfaces: Implications for Structural Superlubricity

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"Structural superlubricity," a state of frictionless interaction between crystalline surfaces, has been observed at both the nanoscale and microscale [1], but achieving it at the macroscale remains an challenge. This study theoretically explores the frictional behavior of macroscale patterned surfaces composed of microscale bumps. Using the discrete element method in LAMMPS [2], we conduct numerical simulations incorporating the Hertz contact model and a modified tangential Mindlin contact model which can present the nonlinear relationship between the coefficient of friction and normal load. Our findings indicate that factors such as the radius of microscale bumps, coating durability, and surface elasticity play a crucial role in friction behavior. Additionally, we analytically examine the deformation mechanisms of the surface structure and derive scaling laws that describe parameter dependencies and the breakdown of superlubricity. The simulation results align closely with analytical predictions, confirming power-law scaling of various quantities with the total macroscopic load. Lastly, we investigate the effects of imperfect conditions, specifically how height variations influence frictional performance.

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Pinning versus Lubricity at Moiré Crystalline Interfaces

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The sliding habit of incommensurately stacked moiré interfaces -- key in mesoscale crystal contact tribology -- can be either smooth (structurally lubric) or pinned [1]. Understanding the mechanisms governing the two regimes, generally separated by a structural transition, is important both scientifically and technologically, involving the rational design of nanoscale devices.

We carried out large-scale molecular dynamics simulations of realistic systems, also extended to 2D Frenkel-Kontorova models where parameters can be varied. Results show that defect-free 2D materials bilayers -- including those consist of graphene, hBN and TMDs -- remain lubric with zero static friction across all conditions examined of incommensurate twist angles, freestanding or deposited, without or with loads. In particular, it appears that a possible Aubry pinning transition would only be possible under unrealistic large loads. The kinetic friction will instead depend upon twist angle and boundary conditions [2, 3], but is predicted to be, in the absence of pinning defects, linear with sliding velocity, ultra-small and hard to measure under ordinary experimental conditions.

Unlike 2D materials interfaces, in fcc Au(111) twist grain boundaries, simulations discover a first-order, load-driven transition from structurally lubric to locked [4]. At a relatively moderate load (≈ 2 GPa), highest energy (so-called) moiré AA nodes collapse forming commensurate mini-domains, also eliminating the adiabatic continuity which is necessary for free sliding. This transition produces a huge friction jump, hysteresis and irreversible plastic flow.

Together, our findings map the key parameters -- twist angle, load, and interlayer strength -- that govern the transition between superlubric and pinned states. They offer guiding principles for the design of frictionless or controllably locked interfaces in future micro/nanoscale systems.

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Deriving constitutive laws for slip using molecular dynamics

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The quantitative description of lubricants in nanoscale channels is complicated by various effects that are often neglected in conventional elastohydrodynamic models. One of those effects is wall slip, a phenomenon that occurs whenever the velocity of a solid wall and the fluid in contact with the wall differ. Slip changes the shear rate of the fluid, thus the shear stress, with respect to the no-slip condition, and we have recently demonstrated the possibility to inform continuum models by parametrizing constitutive slip laws with molecular dynamics [1]. There is evidence for friction reduction in the elastohydrodynamic regime due to slip [2], which is connected to the limited momentum transfer, i.e., energy dissipation, between the lubricant molecules and the surface. However, some authors suggest that thermal effects, which change the viscosity of the fluid, are responsible for low friction [3]. We performed an extensive molecular dynamics study on the effect of temperature on the slip of a polyalphaolefin base oil in a nanosized amorphous carbon channel. We observed that higher temperatures promote the slip of the lubricant molecules on the surfaces, changing the parameters of the Eyring constitutive law [4], which describes slip as an activated process. Here, we discuss the intricate relationship between temperature effects, viscosity and slip. Our aim is to understand whether low friction originates from the local effect of slip [2], or it is the result of a decrease in viscosity due to heating [3]. Furthermore, we derive a non-isothermal slip law to further extend the validity of continuum models for lubrication.

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Tribological characterization and numerical simulation of semi-solid lubricant in mixed lubrication regime

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Accurate prediction of friction in metal forming processes remains a critical challenge, particularly under conditions of boundary and mixed lubrication. In this study, a semi-solid lubricant used in aluminum sheet metal forming [1,2] was characterized to evaluate its rheological behavior and tribological performance under varying temperature and sliding velocity conditions. Additionally, the boundary layer shear strength of the lubricant was evaluated as a function of contact pressure, sliding velocity, and temperature, providing essential input for developing a friction model that captures the temperature- and velocity-dependent nature of lubricant behavior.

The effect of surface topography on lubricant pressure distribution and frictional behavior in the mixed lubrication regime have been studied through a numerical approach based on the average Reynolds equation and finite difference method [3]. Experimental inputs from the rheological characterization and boundary layer shear strength measurements were integrated into the model to ensure an accurate representation of lubricant performance under realistic forming conditions. This approach enables a more predictive friction calculation framework, contributing to the optimization of lubricant design and surface engineering strategies in metal forming applications.

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Machine learning algorithms for prediction of dry friction coefficient on DLC coatings

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Nowadays, diamond-like carbon (DLC) coatings are recognized as efficient solutions for reduction of dry friction coefficient (CoF). However, understanding the tribological behavior of these coatings and how various material and operational parameters influence their performance is essential for their successful implementation in industrial environments.

In this study, we present machine learning models to predict dry CoF on DLC coatings. Our models use a continuously growing dataset of over 100 scientific articles and more than 800 datapoints. The dataset includes key parameters such as the Sp^2/Sp^3 ratio, coating roughness, hardness, thickness, contact pressure, temperature, humidity, sliding velocity, and more. The models are trained and validated using an 80/20 data split, and their performance is assessed through root mean squared error (RMSE), mean absolute error (MAE), and coefficient of determination (R^2) metrics.

Our study explores the capabilities and limitations of current models in the prediction of CoF, focusing on the balance between generalization and accuracy. Fig. 1 shows that the predicted and actual CoF values are aligned, demonstrating the models' ability to capture key trends across heterogenous dataset. These findings provide promising paths for refining predictive accuracy and challenging current approaches, driving the development of robust and versatile AI-driven methodologies in tribology.

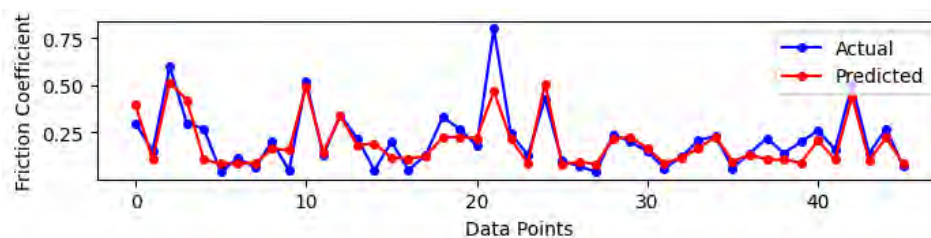


Fig. 1 Comparaison of predicted and actual CoF for Artificial Neural Network model

Effects of the composition of train brake friction materials on the emission and properties of wear particles

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Wear particles emitted by brakes are a significant source of particulate matter in the air, which contains toxic components like heavy metals and resins. With a growing fleet of cars, buses, trams and trains, more and more brake wear particles are emitted into the atmosphere, which is particularly noticeable in semi-closed environments such as railway stations.

The emission rate, size distribution, morphology and elemental composition of airborne wear particles emitted from friction materials for train brakes were investigated in relation to the type and content of binder, filler and reinforcing ingredients [1, 2]. The particles were generated using a pin-on-disc tribometer with the friction pair in an aerodynamic chamber. They were counted, classified by size and collected using various aerosol measurement instruments. The morphology and elemental composition of the particles were analysed using scanning electron microscopy and energy dispersive X-ray spectroscopy.

It was found that the particle size distribution peaks at 0.15, 0.5 and 1.6 μm . Particles of order 1.6 μm have a flaky shape and are generated via abrasive wear. Smaller particles have a more rounded shape and are most likely generated via abrasive and adhesive wear. Most of the particles composed predominantly of iron originate from the wear of steel disc sample. Replacing styrene butadiene rubber with nitrile butadiene rubber reduces the emission of 0.1–10 μm particles. The addition of steel fibre leads to a more intensive emission of 0.3–10 μm particles than the addition of copper fibre. The copper content in 1–10 μm particles increases with the copper content in the friction material.

This work was supported by the 'Excellence Initiative — Research University' programme of Gdansk University of Technology through the grant DEC-3/1/2024/IDUB/II.2b/Np under the Neptunium Enhancing Baltic Region Research Cooperation and the grant DEC-1/1/2022/IDUB/I3B/Ag under the Argentum Triggering Research Grants.

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Temperature management in radial-shaft-seal contacts using additively manufactured porous shafts

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The service life of radial shaft seals (RSS) is significantly influenced by their thermal load during operation, as the frictional power due to the high contact pressures leads to substantial over-temperatures in the contact-zone. Particularly with RSS made of nitrile butadiene rubber (NBR) this often causes local hardening of the elastomer [1], which can impair the sealing mechanism, inter alia, due to limited followability under shaft runout and crack formation [2].

In general, the time- and temperature-dependent aging resistance of elastomer materials can be empirically described with respect to a defined lifetime criterion (e.g. critical hardening in NBR) and translated into a service life estimation [3]. However, artificial aging tests conducted in air or oil neglect the tribological loads acting on RSS [4]. These effects could be implicitly accounted for by using the contact temperature as an input parameter in established aging model approaches [3], thereby enabling more accurate predictions of thermally induced local material aging and the resulting expected service life.

Based on such an approach, measures aiming for lifetime extensions and expansion of permissible shaft speeds can be evaluated. In this context, the present study investigates a contact temperature reduction, achieved by employing actively cooled porosities (implemented as lattice structures) into the shaft. This principle has been previously demonstrated on tilting pad journal bearings, the sliding surface temperature of which was reduced through enhanced heat exchange of up to 50 % [5]. The current work aims to transfer this concept to sealing applications using shafts produced via powder bed fusion from 316L stainless steel.

Acknowledgment: Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 511263698 - TRR 375 / Project-ID 466192751 - SPP 2305

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Influence of temperature on tribological properties of different thermoset/thermoset material pairs under water lubrication for pump applications

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As the automotive industry shifts toward green mobility, electric vehicles (EVs) require lightweight, electrically insulating materials to enhance efficiency and safety. Thermoset composites offer superior performance compared to thermoplastics, enabling the replacement of metal components even in most demanding applications. Key advantages include reduced weight, enhanced resistance to temperature, humidity, and chemicals, and excellent electrical insulation—critical for EV systems. However, the limited scientific understanding of thermoset tribology in critical contacts such as involute gear meshing, sliding bearing radial and axial contacts, hydraulic piston-cylinder contacts, hinders material selection and optimization for EV applications.

In this study we investigated the effect of temperature on tribological performance of thermoset composites under water lubrication using a pin-on-disc tribometer, optical microscope, scanning electron microscope and Raman spectroscopy. Two material pairs were tested: Material pair 1 (glass fibers/glass beads versus glass fibers and mineral dust) and material pair 2 (short carbon fibers versus glass fibers and mineral dust). At room temperature, material pair 2 showed superior wear and friction performance under all test conditions (sliding velocities of 0.5 and 3.2 m/s; contact pressures of 20, 40 and 80 MPa). However, at elevated temperature (60°C), material pair 1 performed better than material pair 2 under identical conditions. Abrasive wear was observed in material pair 1, which was less pronounced at 60°C in agreement with the wear results. In contrast, material pair 2 showed plastic deformation of the matrix, which was more pronounced at 60°C. These results provide valuable insights for the optimization of thermoset composites for EV tribological applications.

Test Bench for Real-Time Estimation of Soil Parameters via the Locomotion Unit's Proprioceptive Sensors

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Terramechanics combines principles from Geotechnical and Vehicle Engineering to study wheel behavior on deformable terrains. The first and most influential model describing how terrain and vehicle parameters affect mobility is Bekker's theory [1], which laid the foundation for many other empirical and semi-empirical models. One of his key contributions was the formulation of the relation between shear stress (τ) and shear displacement (j) in deformable soils under a given normal stress (σ): $\tau = (c + \sigma \tan \phi)(1 - e^{-\frac{j}{k}})$, where cohesion (c) represents the soil's resistance to particle separation, and the internal friction angle (ϕ) describes its ability to withstand shear stress.

This work presents an instrumented tyre with proprioceptive sensors for real-time soil parameters estimation, enabling terrain classification while navigating. The minimum target is to classify the soil type by estimating c and ϕ from measured variables, similar to [2,3],

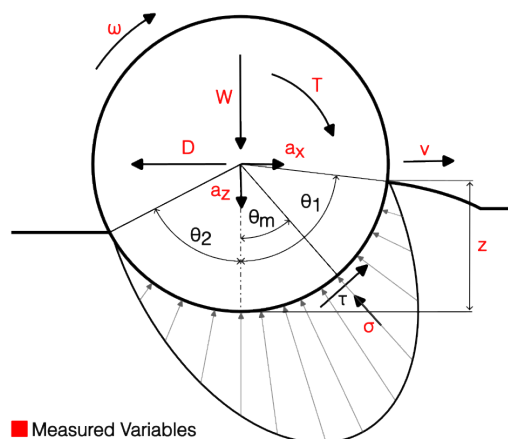


Fig. 1: Rigid wheel on deformable terrain

but using a system designed to adapt to different wheels and vehicles. The functional scheme (Fig. 1) features a single wheel instrumented with sensors to measure forces (W) and (D), torque (T), contact pressure (σ), angular velocity (ω), linear accelerations (a_x) and (a_z), and wheel sinkage (z). Future developments may extend beyond terrain classification to estimate additional soil parameters relevant for agricultural monitoring, such as water content or compaction.

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Use of micro-Raman spectroscopy in tribological studies: The case of metal nitride coated tungsten carbide pins dry sliding on steel discs

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Ex-situ micro-Raman spectroscopy is utilized to probe tribological processes occurring when tungsten carbide pins, PVD-coated with a single layer of metal nitride or binary metal nitride thin film (TiN / TiAlN / AlCrN), are slid against hardened steel discs under dry conditions. The study is relevant to the machining industry where such coatings are commonly applied on cutting tools to enhance wear resistance and thereby increase tool life and productivity.

Optical and acoustic phonon bands from the crystalline coatings appearing in the Raman spectra are analyzed to assess structural changes in the coatings upon dry sliding. Spatially-resolved, micro-Raman spectra reveal that different iron oxide phases are formed at the interface and adhere differently to the pins depending on the nature of the coatings. The onset of coating degradation could also be reliably assessed using the intensity ratios of the Raman bands. Intermittent tribo-tests were performed to study the time evolution of the iron oxide phases and structural changes occurring in the coatings.

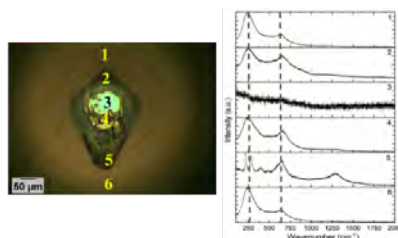


Fig. 1: Spatially-resolved micro-Raman spectra measured on a worn pin head

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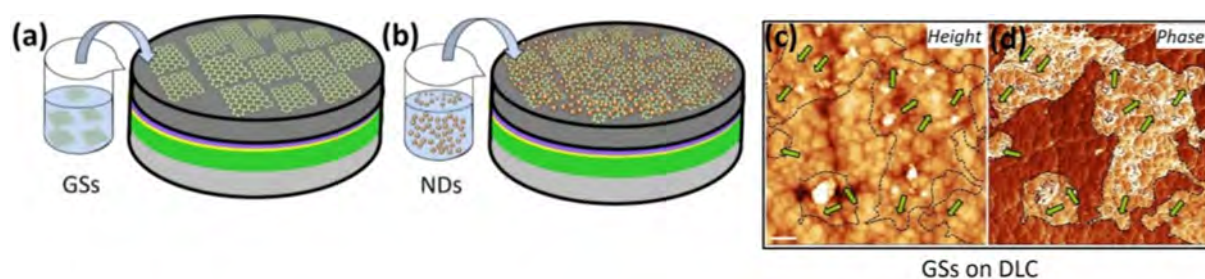


Fig. 1 First (a) and second (b) treatment with GSs and NDs, respectively. AFM images of GSs deposited on DLC: (c) height and (d) phase signals. Typical graphene wrinkles visible in both signals are highlighted by the arrows (scale bar 1 μm).

Self-healing Transparent Super Slippery Surfaces for Drag-Reduction and Anti-Icing Applications

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Transparent slippery liquid-infused porous surfaces (SLIPS) are highly sought after and have significant applications across a range of industries like anti-icing, drag-reduction, etc. However, striking a balance between employing sustainably sourced materials for fabrication and achieving high application durability poses challenges. This study uses Polydimethylsiloxane (PDMS) as a substrate owing to its non-polar behavior and favorable physical characteristics. It develops a transparent, robust, slippery coating by avoiding fluoride contamination and other low surface energy treatments harmful to the environment. The SLIPS samples demonstrated high transparency ($\sim 90\%$) in the visible light range, remarkable wettability with sliding angle (SA) $<5^\circ$ for a range of liquids with low surface tensions, and a low contact angle hysteresis (CAH $<6^\circ$) for efficient droplet mobility. The durability experiments portrayed excellent retention of super slippery behavior with samples retaining SA $<5^\circ$ after exposure to an ultrasonication environment for 2.5 hours and multiple high-speed droplets impinging on it. The slippery behavior of the sample was also maintained when exposed to different acidic and basic environments, highlighting the ubiquitous nature of the employability of the sample. The developed SLIPS showed a $\sim 60\%$ reduction in ice adhesion and $\sim 70\%$ reduction in drag reduction compared to an untreated PDMS substrate, demonstrating optimal applicability in these industries. Moreover, when exposed to different contaminants, the samples exhibited remarkable self-cleaning and anti-staining characteristics, enabling their applicability in a plethora of applications.

Keywords: SLIPS, Drag-reduction, Anti-icing, Self-cleaning, Self-healing

Tuesday, 2025-07-29		HG E7	HG E5	
Invited Talks	9:00-9:45	Chair: Nicholas Spencer Nuria Espallargas: Status and future prospects of Environmentally Acceptable Lubricants and green additives		
	9:45-10:30	Stefan Eder: Atomistic Insights for Engineering: Computational Pathways to Advanced Materials and Lubricant Design		
Coffee and Posters		10:30-11:30	10:30-11:30	
Sessions	Micro/Nano I	Chair: Rowena Crockett	Coatings III	Chair: Lars Pastewka
Talk 1	11:30-11:50	John Pethica: Static friction: initial slip in contacts	11:30-11:50	Shisheng Lu: Microstructure and high-temperature wear performance of laser-cladded Co-Mo2C coating with NiCu interlayer on ductile iron
Talk 2	11:50-12:10	Simon Scherrer: Measuring Rolling Friction at the Nanoscale	11:50-12:10	Nan Xu: Wear Monitoring via a Raman-Based Bilayer Coating System
Talk 3	12:10-12:30	Nicholas D. Spencer: Tribology of Wine in the Mouth	12:10-12:30	Milena Gleirscher: The effect of surface texturing on the friction and wear behavior of laser-induced graphene films
Talk 4	12:30-12:50	Matthias Freisinger: Micro-mechanical testing as a novel tool to unveil the characteristics of White and Brown Etching Layers	12:30-12:50	Raphael Scharf: Under (Hydrodynamic) Pressure: Investigating Single- and Multi-Dimple Textures Under Varying Conditions
Lunch and Posters		12:50-14:00	12:50-14:00	
Sessions	Micro/Nano III	Chair: Nuria Espallargas	Coatings IV	Chair: Oleksii Nosko
Talk 5	14:00-14:20	Jay Fineberg: The Fundamental Physics of the Onset of Frictional Motion: How does friction (or an Earthquake) start?	14:00-14:20	Mohammad Alinezhadfar: Wear Mechanism of Modified Zinc Phosphate Conversion Coatings Under Lubricated Sliding
Talk 6	14:20-14:40	Daniel M. Mulvihill: Mechanics and Tribology of Triboelectric Nanogenerators	14:20-14:40	Xiaobo Zhou: Surface modification of bearings to enhance the performance
Talk 7	14:40-15:00		14:40-15:00	Naiara Sebbe: Analysis of the wear behaviour of TiAlN/DLC, CrN/DLC and TiAlTaN coated tools in milling of AMPCOLOY® 83: a comparative study
Coffee and Posters		15:00-16:00	15:00-16:00	
Sessions	Micro/Nano IV	Chair: Nicholas Spencer	Coatings V	Chair: Filippo Mangolini
Talk 8	16:00-16:20	Wilfred Tysoe: Molecular Origins of Tribology: From Reactions to Shear Thinning	16:00-16:20	Ryo Goda: Chemical State Analysis and Tribological Characterization of Transferred Carbon Films by X-ray Absorption Spectroscopy in the Soft X-ray Region
Talk 9	16:20-16:40	Markus Varga: Visualisation of dynamic effects in tribocontacts	16:20-16:40	Pierluigi Bilotto: Sustainable two-dimensional materials and their applications in tribology
Talk 10	16:40-17:00	Hinano Egawa: Nano-Tribological Properties of Metal-Based 2D Material MXene in Combination with Adsorption-Type Additives	16:40-17:00	Fedor Klimashin: Hard Ceramic Coatings with Superior Toughness and Wear Resistance by Industrial-Scale Sputter Deposition
Apéro and Banquet in Kunsthaus 18:00-22:00				

Measuring Rolling Friction at the Nanoscale

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Colloidal probe microscopy enables the measurement of nanoscale friction and is, therefore, pivotal in both applied and fundamental research related to nanoscience. Typically, a single microparticle is permanently attached to the tip of an atomic force microscopy (AFM) cantilever and translated horizontally at a specified normal load to measure the respective lateral force originating from the contact. This conventional setup only allows the measurement of sliding friction.

Nevertheless, in many particle-based materials, such as highly concentrated suspensions, particle interactions are based on sliding and rolling. This necessitates techniques to quantify and study sliding and rolling friction. Here, we introduce an approach to measure normal and lateral forces of rolling particles based on a modified AFM [1]. We fabricate customized attachments to regular AFM cantilevers that enable the reversible trapping of individual microparticles while allowing their free rotation.

Depending on the interactions between the particles and the substrate that they are translated across, either rolling or sliding can occur. Surface properties such as roughness or adhesion affect the traction between the particles and the substrate and, in turn, their motion. This methodology advances nanoscale rolling contact characterization, improving our understanding of contacting particles and providing insights into how particle surface engineering can affect the macroscopic characteristics of particle-based materials.

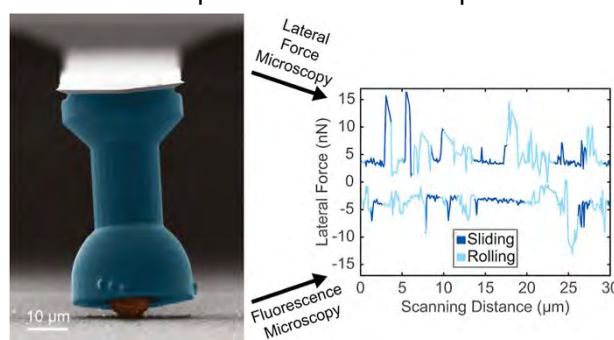


Fig. 1 Representative false-colored scanning electron microscopy image of the experimental rolling friction setup. The local particle motion is visualized in the friction loop [1].

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Tribology of Wine in the Mouth

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Our bodies encounter friction and lubrication phenomena continuously, and we are used to the fact that we fall over if our feet have insufficient friction against the floor. Many of us who are contact-lens wearers are all-too familiar with the discomfort associated with insufficient lubrication/excessive friction between our eyes and eyelids. The key element that links tribology and wine is...saliva! Saliva is the lubricant in our mouths, and if we think of our mouths as tribometers, the mechanoreceptors embedded in the oral tissue are the force sensors. *Mouthfeel* is an important part of the enjoyment of wine and can largely be attributed to changes in the friction sensed in the mouth, as various foods or drinks pass through it.

One of the most important components of mouthfeel in wine is *astringency*, often perceived as a drying, rough, or puckering sensation in the mouth. The main components of wine responsible for this sensation are tannins and, to a lesser extent, the acidity. Recent work from groups in Australia has described an elegant series of experiments, in which the friction between saliva-coated model surfaces was measured, before and after adding model wines containing varying amounts of tannins and acidity. Not only was the effect of these components very noticeable in the friction measurements, but the tribological results correlated impressively with specific descriptors provided by a taste panel, presented with the same set of model wines.

Current research in which I am involved, is aiming to extend this work by fabricating more realistic saliva-covered model surfaces, using the tools of surface chemistry, and to explore the mouthfeel deficiencies that currently make many low- or no-alcohol wines less than pleasant to consume.

Micro-mechanical testing as a novel tool to unveil the characteristics of White and Brown Etching Layers

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Microstructural changes in near-surface regions of tribological contacts play a crucial role in determining friction, wear, and the overall performance and reliability of tribological systems. One of the most crucial near-surface microstructural changes is the formation of white and brown etching layers. Traditional testing methods are often limited for evaluating local mechanical properties due to the small-scale and confined nature of near-surface microstructures, hence, small-scale testing techniques offer enormous potential.

In this study the microstructure of white and brown etching layers formed on a ferritic-pearlitic rail wheel and a martensitic roller bearing are examined after tribological contact [1]. The work focuses on the application of the *in-situ* micro-cantilever bending method to evaluate the local micromechanical properties of these complex multiphase materials, emphasizing their role in understanding the behavior of tribological systems.

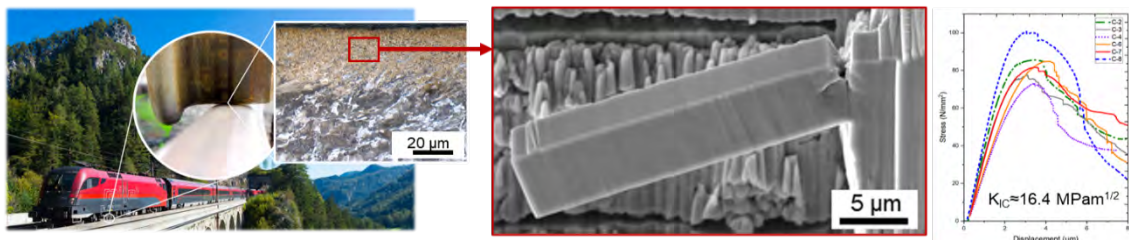


Fig. 1 Micro-bending test on near-surface microstructure of a rail wheel from service.

The findings highlight that micro-testing methods can identify ductile and brittle zones within the microstructure while providing fracture mechanic values such as J -integral and local fracture toughness K_{IC} . Hence, the approach offers valuable insights into the microstructural and micro-mechanical properties of tribological contacts that can not be accessed using conventional mechanical tests. This approach aids in improving the performance and efficiency of mechanical components, while also providing a more detailed method for characterizing tribological systems at the micrometer scale.

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The Fundamental Physics of the Onset of Frictional Motion: How does friction (or an Earthquake) start?

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Recent experiments have demonstrated that rapid rupture fronts, akin to earthquakes, mediate the transition to frictional motion. Moreover, once these dynamic rupture fronts (“laboratory earthquakes”) are created, their singular form, dynamics and arrest are well-described by fracture mechanics. Ruptures, however, need to be created within initially rough frictional interfaces, before they are able to propagate. This is the reason that “static friction coefficients” are not well-defined; frictional ruptures can nucleate for a wide range of applied forces. An important open question is, therefore, how the nucleation of rupture fronts actually takes place. We experimentally demonstrate that rupture front nucleation is prefaced by extremely slow, aseismic, nucleation fronts. These nucleation fronts, which are often self-similar, are not described by our current understanding of fracture mechanics. The nucleation fronts emerge from initially rough frictional interfaces at well-defined stress thresholds, evolve at characteristic velocity and time scales governed by stress levels, and propagate within a frictional interface to form the initial rupture from which fracture mechanics take over. We will briefly describe a new theoretical description of the nucleation process obtained by means of a nontrivial extension of fracture mechanics. This theory quantitatively describes all of the experimentally observed features of the extremely slow nucleation process and merges seamlessly with the accepted fracture mechanics description of rapid dynamic ruptures. These results are of fundamental importance to questions ranging from earthquake nucleation and prediction to processes governing material failure.

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Mechanics and Tribology of Triboelectric Nanogenerators

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Triboelectric nanogenerators (TENGs) are a promising energy harvesting technology receiving significant global attention at present. This talk will explore the mechanics and tribology of TENGs in normal contact separation mode and demonstrate just how mechanics can have an important effect on electrical output. In particular, we focus here on the effect of the following parameters: contact force, 'real' contact area and surface roughness. Results published in the literature [1] have indicated that TENG electrical output appears to be very sensitive to aspects like contact force and surface roughness. We show that this dependency really results from how the so called 'real' contact area of rough surfaces responds to changes in contact force and roughness. In this talk, we will also explore approaches for *in-situ* measurement of the real contact area. Our TENG tests concurrently measure both TENG electrical output and real contact area over a wide range of contact forces and surface roughness values. Fig. 1 illustrates an optical technique for measuring the real contact area and shows area maps for different surface roughnesses (same force here). The electrical results show that power drops as the contact area drops in line with the surfaces getting rougher. The important implication is that surface topography and contact force must be carefully considered in the design of TENGs and their output can clearly be optimised by optimal selection of surface topography, mechanical properties of the contacting materials and contact force (or pressure).

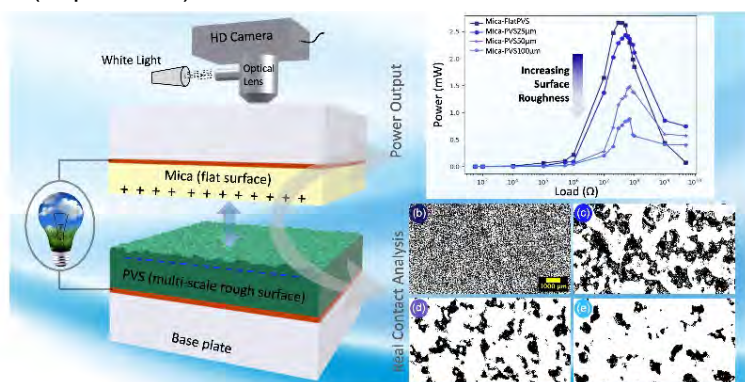


Fig. 1 In-situ measurement of contact area in triboelectric nanogenerators.

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Molecular Origins of Tribology: From Reactions to Shear Thinning

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While tribological theories are generally framed in the language of continuum mechanics, tribological processes are fundamentally controlled by the way in which the atoms and molecules in the materials response to applied stresses. The connection between disparate tribological processes, from friction, to tribochemistry to fluid viscosity is that the activation barrier for the transition from one state to another is modified by an external force [1].

The basic concept that underpins chemical theories is the potential energy surface (PES), which gives the energy of all atoms in a chemical system as a function of their position and can be calculated using quantum mechanics. Local minima on this PES correspond to metastable chemical structures and chemical reactions occur when a collection of atoms transits from one metastable structure to another. This process occurs by the system transiting an energy barrier on the PES. However, calculating all possible trajectories from the reactant to the product would be a daunting task, so that a simplification is made that the reaction pathway is dominated by a pathway that passes over the lowest-energy saddle point between the reactant and the product. This simplification has the advantage of reducing a complex, multi-dimensional problem into one in one dimension. The energy of the saddle point, known as the transition state, relative to the reactant, is the activation energy, E_{act} , and the reaction rate constant is proportional to $\exp(-E_{act}/RT)$, where R is the gas constant and T is the absolute temperature. Evans and Polanyi showed that the rate of a process can be modified by some stress, σ , by a factor $\exp((\sigma \cdot \Delta V^\ddagger)/RT)$, where $\Delta V^\ddagger$ is an activation volume [2]. This modification to transition-state theory allows the analysis of chemical reaction rates, [3, 4], shear stresses,[3] and viscosity [5].

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Visualisation of dynamic effects in tribocontacts

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New lubricant formulations, coatings, materials, etc. for tribosystems are often based on outcomes from tribological model tests. Although it is known that a tribometer, as a mechanical-dynamic system, has a notable influence on the tribocontact under investigation, we usually only focus on the measurement results: when analysing the data we neglect the tribometer and consider it as a black box. In the presented work we used high-sophisticated measurement equipment to investigate the tribometer and its influence on the coefficient of friction in a lubricated contact.

As model-system an SRV® tribometer was used. The counterbody was our developed “tribo-acoustic pin”, i.e., a steel ball equipped with an ultrasonic sensor allowing for online film thickness measurement. To understand the dynamic behaviour a high-resolution high-speed camera for visual imaging and a high-sophisticated 3D scanning vibrometer were used. Thereby, the movement and vibrations of the tribometer (sample holder, housing, etc.) were observed in detail and correlated to fluctuations in film thickness and coefficient of friction.

The sample holders of tribometers with reciprocating motion with high frequency exhibit considerable relative movements, sometimes in “unexpected directions”, depending on the prevailing friction coefficient as clearly visualized with high-speed imaging and vibrometry. These vibrations entail a detrimental influence on the stability of the normal force and reactions in the tribocontact, e.g., film thickness and tangential force. Especially, the online film thickness measurement allowed for the *operando* monitoring of the current lubrication condition. As expected, lubricants forming a tribofilm show clear benefits over non-additivated base oils. Nevertheless, a thinner film does not necessarily goes in hand with a higher coefficient of friction.

Acknowledgments

This work was carried out as part of the COMET Centre InTribology project (FFG no. 906860). funded by the federal ministries BMIMI and BMWET as well as the federal states of Niederösterreich and Vorarlberg. The authors are grateful for infrastructure funding for “5D High-Speed Visualizing” provided by the “NÖ Wirtschafts- und Tourismusfonds” under the grant WST3-F-5030642/023-2021. Part of the work was also funded by the Interreg project “IPMAI” ATCZ00060.

Nano-Tribological Properties of Metal-Based 2D Material MXene in Combination with Adsorption-Type Additives

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Two-dimensional (2D) materials with layered structures exhibit low interlayer shear strength, which enables friction reduction through interlayer sliding. MXenes, metal-based 2D materials, have demonstrated friction-reducing effects when used as coatings or additives. In parallel, adsorption-type additives, composed of polar and hydrocarbon groups, form an adsorbed film on metal surfaces, reducing direct contact between metals and thereby lowering friction.

In this study, we investigated the tribological properties of MXene in combination with adsorption-type additives using atomic force microscopy (AFM). Stearic acid was employed as the adsorption-type additive. MXene was spin-coated onto silicon substrates, and surface observations were performed in both air and lubricating oil. MXene flakes approximately 5 μm^2 in size were observed. Subsequently, MXene was also coated onto copper and iron substrates, and friction measurements were conducted in lubricating oil using a silica colloidal probe cantilever. MXene alone contributed to friction reduction, and further decrease was confirmed when used in combination with the additive. The results of evaluating the interlayer friction of MXene, using a MXene-coated cantilever sliding on a silicon substrate coated with MXene, will be reported in the presentation.

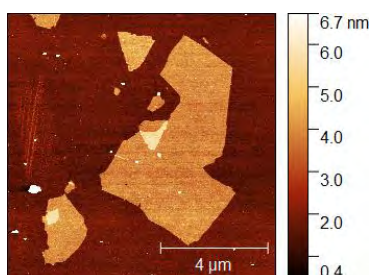


Fig. 1 AFM image of MXene

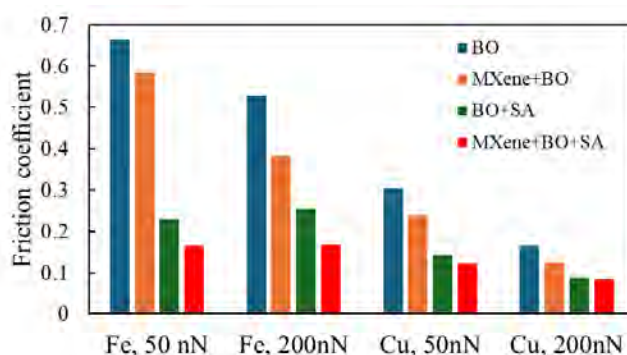


Fig. 2 Average of friction measurements

Microstructure and high-temperature wear performance of laser-cladded Co-Mo₂C coating with NiCu interlayer on ductile iron

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Ductile iron has excellent castability, friction reduction and machining properties. But the poor high-temperature tribological properties shorten the service life as well as limit the practical application^[1]. In order to improve the high temperature wear resistance of ductile iron, the CoCrNiW coatings with 10wt% and 20wt% Mo₂C were prepared on the ductile iron. The NiCu transition layer was manufactured to restrain the diffusion of C element in substrate and control the chilled structure at the interface between coating and substrate. There are no obvious cracks or pores inside the coatings. The CoCrNiW coatings with different contents of Mo₂C were composed of the same matrix phase of γ -Co as well as Cr₇C₃ and M₂₃C₆ for 0 wt% Mo₂C, Co₇Mo₆, Co₆W₆C, Fe₆W₆C and Cr₇C₃ for 10 wt% and 20 wt% Mo₂C, respectively. As the Mo₂C content increases, the contents of Co₇Mo₆, Co₆W₆C, Fe₆W₆C and Cr₇C₃ in the coating rise. The CoCrNiW coatings with 20 wt% Mo₂C demonstrate a fine microstructure, superior mechanical properties, which improve the tribological properties. The wear mechanism of CoCrNiW coating with 20 wt% Mo₂C were slight adhesive wear and abrasive wear at medium-low temperature (from room temperature to 400°C) and formation of smooth glazed layer containing MoO₃ and NiMoO₄ on the worn surface at high temperature (from 600°C to 800°C).

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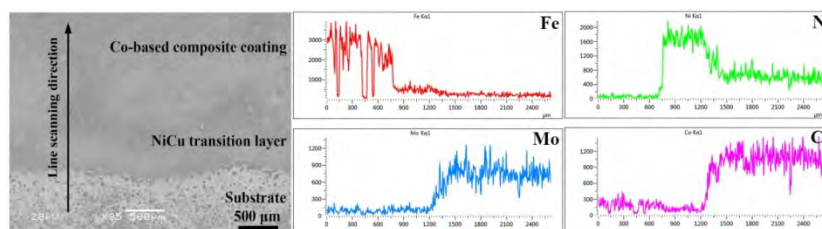


Fig.1 Cross-sectional SEM image and line scanning of CoCrNiW coating with 20 wt%Mo₂C

Wear Monitoring via a Raman-Based Bilayer Coating System

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Current wear monitoring methods rely mainly on indirect signals, limiting early detection capabilities at the component level. This study introduces a novel bilayer coating system for direct, real-time wear monitoring of steel components. The system integrates a diamond-like carbon (DLC) top layer for enhanced wear resistance and an optimized crystalline silicon sensing underlayer suitable for Raman spectroscopy. Although high silicon crystallinity is essential for strong Raman signals, it traditionally causes increased grain size variability and surface roughness, leading to measurement inconsistencies. To overcome these issues, deposition parameters were rigorously optimized, effectively controlling silicon grain growth. The resulting multilayer coating demonstrated reliable differentiation among wear stages (running-in, steady-state, and accelerated wear) and precise identification of coating failure. This innovative approach enables direct wear monitoring, facilitating predictive maintenance strategies, reducing lubricant usage, and enhancing energy efficiency.

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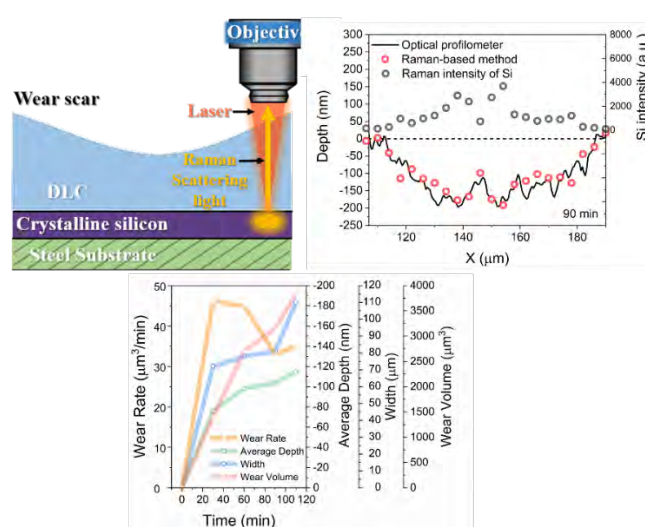


Fig. 1 Schematic illustration of the coating thickness quantification process and its application in wear monitoring.

The effect of surface texturing on the friction and wear behavior of laser-induced graphene films

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An exciting strategy to influence the tribological behavior of a surface is to modify the involved surface topographies by introducing different textures [1]. One approach, based on transformative Direct Laser Writing, is irradiating a suitable precursor material with a laser source, which leads to the formation of laser-induced graphene (LIG) on the surface. This technique can be employed to fabricate different LIG patterns in a single-step, fast, chemical-free, and maskless process using commercially available laser engraving equipment [2].

Herein, we explore the tribological behavior of the fabricated graphenic films and evaluate the influence of different line patterns in a linear reciprocating ball-on-plate setup. It was discovered that a reduction in line sizes and spacings leads to a lower coefficient of friction. The resulting wear tracks were investigated to identify possible underlying mechanisms.

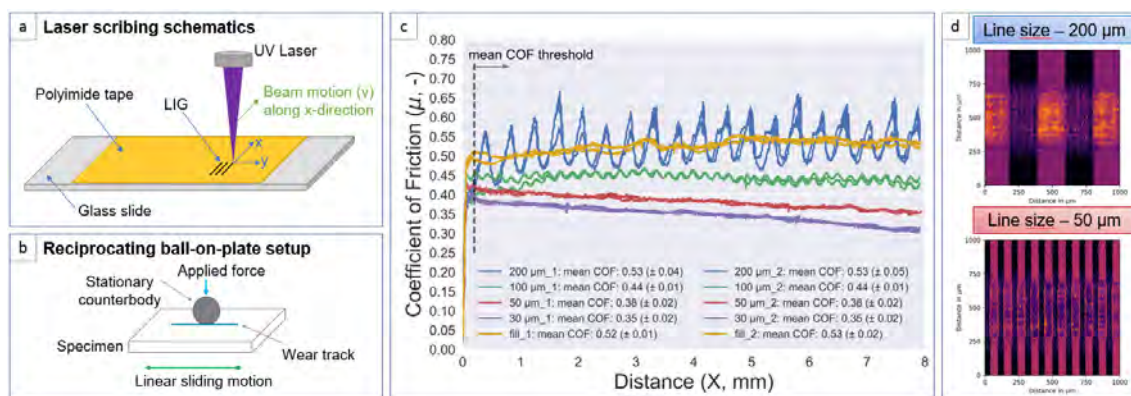


Fig. 1 a) schematics of laser scribing of LIG on polyimide, b) schematics of linear reciprocating ball-on-plate tribological testing, c) resulting friction curve of different line patterns for a single cycle, and d) confocal microscopy images of the resulting wear tracks.

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Under (Hydrodynamic) Pressure: Investigating Single- and Multi-Dimple Textures Under Varying Conditions

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Surface modifications are already used in lubricated sliding contacts, e.g. cylinder liners of an internal combustion engine. In contrast, applying textures in full-film lubrication is still under research. One potential application are hydrodynamic thrust bearings, which are essential in power plants. Crucial for such a bearing, is a convergent oil film gap.

Many studies analyze the performance of textures on a parallel oil gap. For example, Fouflias et al. [1] simulated different textures on a flat thrust bearing and exhibited that the open pocket bearing leads to the highest load carrying capacity. Gao et al. [2] found in experiments with multi textures, that they could increase the load carrying capacity significantly, compared to an untextured parallel oil film gap. In contrast to these studies, the performance of single- and multi dimple textures on a convergent oil film gap is investigated in this work. For this purpose, the test methodology of Pusterhofer et al. [3], measuring the oil film gap height, is used and further developed. To ensure, that friction forces of around 1N can be measured, the force is transmitted to an external load cell (cf. Fig. 1). The disc rotates and the texture is applied on the stationary pin. In [4], a texture that can be produced time- and cost-efficiently is found numerically and utilized in this work (cf. Fig. 1).

The conducted experiments show, that the performance of textures is influenced by several parameters and that the range of beneficial operating conditions for surface textures is limited.

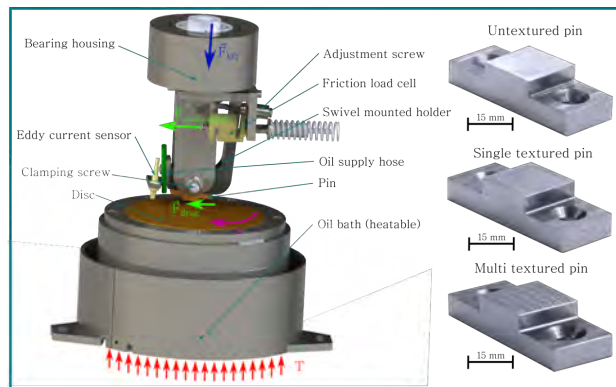


Fig. 1 Schematic test rig and specimens

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Tribological Behavior of Novel Zinc/Zinc-Phosphate Composite Coatings

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Zinc coatings are renowned for their exceptional corrosion resistance and sacrificial anodic behavior on steel substrates, and are extensively utilized in industry [1]. However, the soft nature of zinc limits its mechanical performance, particularly in terms of hardness and wear resistance [2]. The addition of hard particles during the electrodeposition of zinc can effectively address these limitations. Recent advancements have demonstrated that the inclusion of reinforcing particles such as diamond, Cr_2O_3 , and SiO_2 can significantly improve the structural compactness, mechanical strength, and tribological performance of zinc coatings, significantly expanding their potential applications [1-3].

This study introduces a novel generation of zinc composite coatings, composed of a zinc matrix and zinc phosphate crystals. This composite structure is designed not only to enhance corrosion resistance but also to meet the mechanical demands of wear-intensive applications. Unlike conventional methods that rely on a suspension of prefabricated particles, these composite coatings form directly during the deposition process. The research focuses on evaluating the effects of various fabrication parameters on the composition and structure of the zinc/zinc-phosphate composite coatings. Mechanical and tribological assessments are conducted. The tribological behavior of pure zinc coatings and zinc/zinc-phosphate composite coatings is comparatively evaluated under sliding conditions.

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Surface modification of bearings to enhance the performance

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Contact lip seals contribute significantly to the friction torque in greased and sealed rolling element bearings. High friction torque in contact seals leads to increased energy consumption and limits bearing operation speed, particularly in high-speed applications. To address these issues, non-contact seals are often used as replacements. However, non-contact seals are prone to water contamination and grease leakage.

Oleophobic coatings, known for their low surface tension and non-stick properties, have shown potential in mitigating these risks. In this study, we applied fluorocarbon-based oleophobic coatings to non-contact seals made of low carbon steel and the counterface shaft. We evaluated the grease leakage of the coated components using custom-built test rigs. The results demonstrate that oleophobic coatings significantly reduce grease leakage in non-contact seals (Fig. 1). In the study, molecular dynamic simulations of the interface between oil and oleophobic coatings is conducted and the results indicate that the presence of CF_3 bonds results in very low interfacial energy. A slip model developed and verified through experiments demonstrates that low wetting hysteresis and low interfacial energy enhance the wall slip effect. This effect is influenced by the heterogeneity of the solid surface, including factors such as roughness, defects, local polarity, and chemical inhomogeneity. These findings provide valuable guidelines for designing oleophobic coating surfaces to optimize wall slip for lubricants.

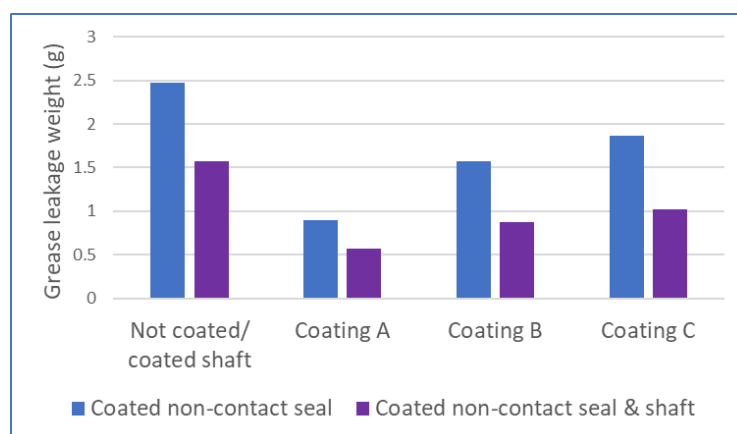


Fig.1 Effect of oleophobic coated non-contact seal (shield) and shaft on grease leakage

Analysis of the wear behaviour of TiAlN/DLC, CrN/DLC and TiAlTaN coated tools in milling of AMPCOLOY® 83: a comparative study

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Machining is a multifaceted technique employed across diverse industrial sectors, particularly for the fabrication of components requiring high dimensional precision and superior surface finish. The milling technique is the most utilized in machining due to its versatility in producing various components. There has also been significant progress in the metal alloys developed, including the Copper-Beryllium alloy, commonly known as inserts, used in plastic injection molds. Consequently, it is essential to enhance the cutting tools employed in the milling process. Coatings on tools have emerged as a crucial element in the machining of novel metal alloys. Based on this, the objective of this work was to carry out a comparative analysis, varying the machining parameters, regarding the wear behaviour of TiAlN/DLC, CrN/DLC and TiAlTaN coated tools, deposited by the HiPIMS sputtering process, in the machining of AMPCOLOY® 83. The compared parameters were feed speed and cutting length. Wear investigation was conducted via scanning electron microscopy, enabling the quantification of wear and the identification of the wear processes associated with each machining condition. The machined surface was assessed to ascertain the resultant roughness and to correlate it with the type of wear shown by the tool and the machining conditions employed. The predominant wear mechanisms identified were abrasion, material adhesion, cutting edge fractures, and chipping. The findings from this study may be utilized to enhance the milling process and surface quality of AMPCOLOY® 83, aiming to augment the efficacy of cutting tools.

Keywords: Machining, Tool wear, Coated tools, Copper-Beryllium alloy, HiPIMS

Chemical State Analysis and Tribological Characterization of Transferred Carbon Films by X-ray Absorption Spectroscopy in the Soft X-ray Region

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In this study, X-ray absorption spectroscopy in the soft X-ray region (SX-XAS) analysis was employed to investigate the chemical state of the transferred carbon films, thereby gaining insights into the friction reduction mechanism of hydrogenated carbon nitride (CN_x:H) coatings under inert gas flow. Sliding tests were conducted using a ball-on-disc tribometer under argon gas flow, with SiC balls and CN_x:H coatings serving as test specimens. The test parameters included systematic variations in the bias voltage during film deposition and the applied load, which have been reported to affect tribological properties. After the tests, the wear tracks on the ball surfaces were analyzed by the total electron yield method using SX-XAS at SPring-8 BL27SU and KEK PF BL-19B.

As a result, the SX-XAS analysis revealed that the transferred film consisted of a CN_x:H coating and a tribofilm that had undergone structural changes due to friction. A strong correlation was found between the tribofilm's quality and the coefficient of friction. When a high-quality tribofilm with a high graphite content was formed, the friction coefficient decreased significantly to approximately 0.01. This behavior is attributed to the layered structure of the graphite-like components, which promotes interlayer sliding. In contrast, while some friction reduction was achieved, the coefficient of friction remained relatively high, at around 0.1 in cases where the tribofilm quality was poor and both graphite-like and diamond-like components were present. This suggests that the presence of diamond-like structures interferes with the interlayer sliding of graphite-like components, thereby limiting the friction reduction effect.

These findings highlight the effectiveness of SX-XAS as a quantitative tool for evaluating the quality of transferred carbon films and contribute to a deeper understanding of the friction reduction mechanism in CN_x:H coatings.

Sustainable two-dimensional materials and their applications in tribology.

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Two-dimensional materials (2DMs) exhibit extraordinary properties due to their dimensionality. Specifically, transition metal carbides and nitrides (MXenes) are a family of 2DMs that have been extensively investigated over the past decades for applications ranging from catalysis and sensing to electromagnetic shielding and tribology.[1] However, the industrial implementation of MXenes is hindered by their synthesis, which predominantly involves the use of HF as a reagent.

We present a novel method for producing MXenes via electrochemistry (EC-MXene).[2] In essence, we separate MXenes from their precursors by breaking the bonds through a selective potential, which is evaluated using detailed electrochemical characterization. During the presentation, I will elaborate on the synthesis process and explain how the synthesis of green materials is connected to the realm of surface nanobubbles.[2] Additionally, I will showcase our latest results on the tribological performance of our sustainable materials. The tribological performance will be discussed in relation to various counter bodies, with detailed surface analytics to elucidate the tribofilm generation and friction mechanisms.

Ultimately, the results presented in this talk align well with the goals of ECOTRIB 2025, demonstrating novel *sustainable-by-design* materials with significant impact on tribological applications.

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Tuesday, 2025-07-29		HG E7		
Invited Talks	9:00-9:45	Chair: Nicholas Spencer Nuria Espallargas: Status and future prospects of Environmentally Acceptable Lubricants and green additives		
	9:45-10:30	Stefan Eder: Atomistic Insights for Engineering: Computational Pathways to Advanced Materials and Lubricant Design		
Tuesday, 2025-07-29		HG E33.1	HG E33.3	
Coffee and Posters		10:30-11:30	10:30-11:30	
Sessions	Boundary Lubricants II	Chair: Michele Barsanti	Friction and Friction Mechanisms I	Chair: Max Marian
Talk 1	11:30-11:50	M. Kamaraj: Optimization of Lubrication Behavior using Novel Bootstrap Procedures for Applications in Marine Tribology	11:30-11:50	Cosimo Mandriota: Adhesion in Viscoelastic Sliding Contacts
Talk 2	11:50-12:10	Amel Krishnan: Effect of DC Current Polarity and Lubricant Additives on Electrified Boundary Lubrication	11:50-12:10	Nicola Menga: The role of friction and finite elasticity in wavy contacts
Talk 3	12:10-12:30	Afrina Khan Piya: Frictional performance of Ti3C2Tx MXenes with nanodiamonds in presence of Organic Friction Modifier	12:10-12:30	André Pedroso: Comprehensive experimental analysis in the drilling of AISI P20 Steel
Talk 4	12:30-12:50	Minnie C. Y. Leung: Mechanochemistry of Antiwear Additive	12:30-12:50	Andrea Plati: Friction dynamics: from control theory to interleaved systems
Lunch and Posters		12:50-14:00	12:50-14:00	
Sessions	Extreme Lubrication II	Chair: Dominika Senajova	Friction and Friction Mechanisms II	Chair: Alessandro Sicilia
Talk 5	14:00-14:20	Wenli Deng: Well-tailored nanostructured films for robust superlubricity at ultrahigh contact stress	14:00-14:20	Malik Rashid Saif Al Naabi: Friction coefficient and work function investigation of transition-metal dichalcogenide
Talk 6	14:20-14:40	Xinchun Chen: Critical advances in ultra-high pressure superlubricity enabled by solid coatings	14:20-14:40	Yuya Yamaguchi: Investigation of Frictional Properties of Ionic Liquids Using Developed FM-AFM/LFM System
Talk 7	14:40-15:00	Zahra Ranjbar-Nouri: The influence of surface topography on lubrication efficiency in cold rolling processes	14:40-15:00	
Coffee and Posters		15:00-16:00	15:00-16:00	
Sessions	Polymer Tribology I	Chair: Jiri Nohava	Friction and Friction Mechanisms III	Chair: Alberto Rota
Talk 8	16:00-16:20	Florian Ausserer: Characterization of Sealing Material Behavior Under Dry Sliding Conditions for a Rotary Compressor Prototype	16:00-16:20	Chinmayee Chowde Gowda: Friction induced Tribovoltaic studies on metal - semiconductor junction
Talk 9	16:20-16:40	Maciej Kujawa: Tribological properties of selected polyhydroxyalkanoates (PHAs), a biobased and biodegradable polymers to be used as sliding materials	16:20-16:40	Charlotte Spies: Negative Slope of the Friction-Velocity Curve in Lubricated Viscoelastic Contacts
Talk 10	16:40-17:00	Dhruv Deshwal: Vibrational Characteristics of Radial Deep Groove Polymer Ball Bearing	16:40-17:00	Aleksandar Marinkovic: New Approach in Friction analyzing and Energy Consumption in Ballroom Dance Performances
Apéro and Banquet in Kunsthau 18:00-22:00				

Optimization of Lubrication Behavior using Novel Bootstrap Procedures for Applications in Marine Tribology

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The current study explores the optimization of tribological behavior of different industrial lubricants used in marine industry. Test conditions like rotational speeds (600rpm and 1200 rpm) and temperatures (30 °C and 75 °C) are varied to characterize the friction and wear behavior for selection of optimal lubricants. Four ball tester instrument is used for carrying out the friction tests. The results of these experiments are analyzed for the first time using novel bootstrap-based trend tests. Coefficient of friction, wear scar diameter, surface roughness and wear depth values are measured for each test condition. Optimal oil and test conditions are estimated from the order-constrained likelihood ratio tests as well as experiments. Statistical results are in perfect agreement to the experimental outcomes. Lower temperature (30 °C) and higher sliding speed (1200 rpm) test conditions indicate better lubrication performance. FTIR analysis helped to predict the chemical bonds and functional groups influencing the lubrication behavior. Nuclear magnetic resonance analysis of these lubricants before and after the tests strongly support the tribo-chemical reactions happening by varying the test conditions as well as structural differences among the oils. Tribo-chemical reaction induces C–C, C=C, C–H, and N–O bond breaking in the complex molecular structure of oils to form shorter hydrocarbon fragments. These fragments recombine and chemically adsorb on the surface of the steel balls, forming low-shear-strength films. They fill the micro and nanogaps over the interacting surfaces to avoid any kind of direct contact. Hydrodynamic lubrication regime is observed at 30 °C whereas at 75 °C a transition to mixed lubrication regime is observed. This is attributed to a thick tribo-film layer at the contact interface, leading to low friction and wear values. This synergistic approach can be extremely helpful for optimizing the friction and wear behavior, thereby substantially reducing the global energy consumption.

Effect of DC Current Polarity and Lubricant Additives on Electrified Boundary Lubrication

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Bearings in electric vehicle powertrains can suffer significant damage due to voltage fluctuations and leakage currents passing through contact interfaces [1]. To improve energy efficiency, low-viscosity lubricants are being explored; however, this increases the risk of boundary and mixed lubrication, especially in high-torque, low-speed conditions often encountered in EV transmissions. Consequently, detailed investigations into the mechanisms of boundary lubrication under electrified conditions are essential.

Studies have reported severe wear under electrified sliding conditions in boundary and mixed lubrication regimes, primarily due to accelerated oxidation and third-body abrasion from oxide debris at the contact interfaces [2]. However, further research is needed to thoroughly understand the wear mechanisms, their kinetics, and the severity of wear at sliding interfaces under electrified conditions.

This study examines the influence of DC current polarity and magnitude on low-viscosity PAO oil-lubricated 52100 steel-on-steel sliding contacts. The electrified sliding tests were conducted using a custom-modified ball-on-disk tribometer, developed in-house to simulate and study current-induced wear in lubricated contacts. In contrast to previous studies, these results reveal a directional wear pattern in lubricated steel contacts under ambient conditions, with significantly higher wear observed at the cathode. Additionally, the study evaluates wear reduction mechanisms using organic friction modifiers and nanoparticles as lubricant additives, demonstrating up to a 30% reduction in wear, highlighting the potential of additive-enhanced lubrication under electrified conditions.

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Frictional performance of $\text{Ti}_3\text{C}_2\text{T}_x$ MXenes with nanodiamonds in presence of Organic Friction Modifier

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Abstract

The tribological performance of $\text{Ti}_3\text{C}_2\text{T}_x$ MXenes combined with nanodiamonds in the presence of glycerol monooleate (GMO), an organic friction modifier, has been examined using polyalphaolefin (PAO) synthetic oil in a pin-on-disc reciprocating tribometer at 80 °C. This additive composition demonstrated a reduction in friction and wear of approximately 75% and 46%, respectively, when compared to a formulation consisting of only oil and $\text{Ti}_3\text{C}_2\text{T}_x$ MXenes. The notable enhancement in frictional performance resulted from the tribochemical interaction among the additives in the lubricant formulation. A synergistic process was noted as a result of GMO adsorption on the steel surface and the incorporation of nanodiamonds into the tribofilm. A durable and thicker tribofilm was generated through the tribochemical interaction. The insights acquired from this study are crucial for the advancement of a more environmentally friendly and efficient additive formulation without toxic sulphur and phosphorus-based compounds. The investigation's outcomes were corroborated by static SIMS, SEM and TEM techniques.

Mechanochemistry of Antiwear Additive

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Zinc dialkyldithiophosphate (ZDDP) is the most widely used AW additive due to its excellent antiwear and antioxidation properties. However, concerns over its environmental impact and its adverse effects on exhaust aftertreatment systems have driven the search for alternatives.

Metal-free organophosphorus-containing compounds, known as ashless AW additives, have gained increasing attentions as potential replacements for ZDDP due to their compliance with stricter environmental regulations and improved compatibility with modern engines. Additionally, they eliminate metal-based component which makes them promising candidates for sustainable lubricant. However, a key limitation of these additives is their inability to form tribofilms with sufficient thickness and mechanical strength at a comparable rate to ZDDP, which compromises their antiwear performance [1].

This study investigates the growth and properties of tribofilms formed by phosphorus-based lubricants under mixed roll-sliding conditions. A mini traction machine with spacer layer imaging mapping (MTM-SLIM) is employed to analyze film formation, friction behavior, and wear protection under mixed rolling-sliding conditions. A key focus is understanding how the growth rates, chemical compositions, and mechanical properties of tribofilms formed by a variety of phosphorus-based additives. These properties are then correlated to the tribological performance of these additives. The chemistry of the wear track is characterised using various microscopies and spectroscopic techniques, such as X-ray photoelectron spectroscopy (XPS) to identify the tribochemical interactions at the interface. Findings from this study will provide insights into optimizing ashless additive formulations, contributing to the development of next-generation environmentally friendly lubricants.

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Well-tailored nanostructured films for robust superlubricity at ultrahigh contact stress

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In the past decades, quantities of studies excavate potentials for promoting lubricity of diamond-like carbon (DLC) films under complex working conditions, aiming at the profound application in the advanced machineries such as aviation, aerospace and nuclear power [1-2]. However, to our best knowledge, there are barely any effective theoretical and technical solutions for facing the challenge of lubrication requirement of DLC lubricants in complex-loading operation environments. This work is dedicated to explore novel nanostructured films with controlling the relevant nanostructures of the overall carbon matrix for achieving a robust superlubricity and figure out the robust load bearing capacities with related to the optimal interfacial properties at high and alternating load contact conditions. A superlow friction coefficient of 0.001 and a near-zero wear rate of $3.13 \times 10^{-9} \text{ mm}^3/\text{Nm}$ were achieved by a thick multilayer film with a bilayer period λ of 324 nm (total film thickness of 1.53 μm) under a peak Hertz contact pressure of 2.37 GPa, as shown in Figure1. At a meanwhile, it is found out that the thick multilayer film also has potential to adapt the alternating contact load conditions. It can be concluded that both the short-ranged sp^2 -ordering structures and the surface hydrogenated passivation is conducive to the building-up easy-shearing sliding interface. While, the newly-grown nanostructures of the carbon matrix at the frictional interface are clarified with respect to the adaption to the complex stress field, which would be the underlying mechanism of lubricity. In short, the well-tailored multicomponent and nanostructured multilayer films indeed offer an effective theoretical and technical solution to the long-term lubrication and protection of mechanical moving parts under ultrahigh loading conditions.

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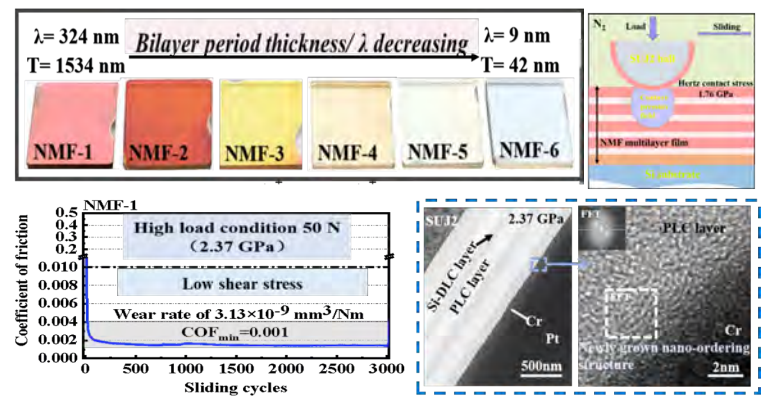


Fig. 1 nanostructured films for robust superlubricity at 2.37 GPa

Critical advances in ultra-high pressure superlubricity enabled by solid coatings

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Superlubricity with near-zero friction and wear characteristics provides a new pathway to elevate the efficiency, durability, and environmental compatibility of various moving mechanical systems. Nevertheless, an on-going challenging regarding this revolutionary technology is the establishment of the anti-friction state and the follow-up maintenance under a complex heavy-load working condition. In this work, some critical achievements with respect to the principles of robust superlubricity under a complicated loading condition and the adaptability to even an ultra-high pressure field by designing various nanostructured solid coatings. Firstly, the intrinsic characteristic of load capacity of a hydrocarbon film is clarified, and the possibility of bearing a few GPa contact pressures is revealed through the architectures of nanoclustering or nano-multilayered structures. The adaptation of superlubricity to stress field strongly relies on the overall thickness and composition of the multilayered carbon films. The heavily-loaded superlubricity is owing to the high stress-induced in situ formation of low-shear strength interfacial ordering structures and the effective constraining of the wide stress field by the local structure. Further on, a new heterogeneous superlubricious interface (Fig. 1) paired from two well-tailored coating lubricants is successfully constructed with the exceptional long lifespan under an extremely high contact stress condition in addition to the vanishing interfacial friction.

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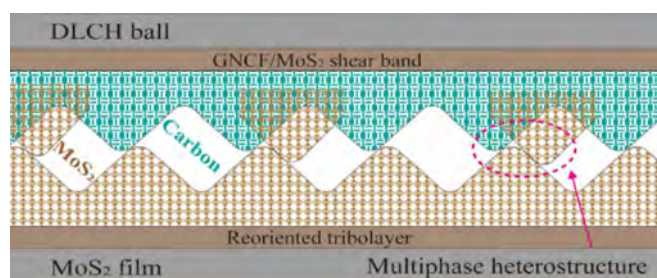


Fig. 1 Heterogeneous interface for ultra-high pressure superlubricity

The influence of surface topography on lubrication efficiency in cold rolling processes

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Hard chrome plating is widely used in various industrial applications due to its exceptional tribological properties, making it ideal for components operating under extreme conditions, such as work rolls in cold rolling. Chrome plating not only enhances the longevity of these rolls but also improves strip cleanliness. However, use of hexavalent chromium in the plating process is banned because of its significant health risks. Despite extensive research into alternative hard coatings, a fully viable replacement for hard chrome plating in cold rolling, where severe operating conditions and high contact pressures exist, remains elusive. Developing effective alternatives requires a thorough understanding of how chrome plating enhances work roll performance in cold rolling.

This study investigates the influence of surface topography on lubrication efficiency in cold rolling processes. Due to the extremely short contact times of the roll surface as well as the use of sprayed emulsion lubrication, dynamic wetting effects play a role in cold rolling. By combining dynamic wetting experiments with topographical characterization, this work provides a comprehensive assessment of surface wettability and topography in chromium-coated steel. Contact angle measurements show that chromium coatings can enhance wettability and wetting speed compared to uncoated steel. Simultaneously, surface topography analysis using confocal microscopy, Power Spectral Density (PSD), and SEM reveals that chromium plating reduces high-frequency roughness, minimizing contact-line pinning and enhancing lubricant spreading efficiency (see Fig.1).

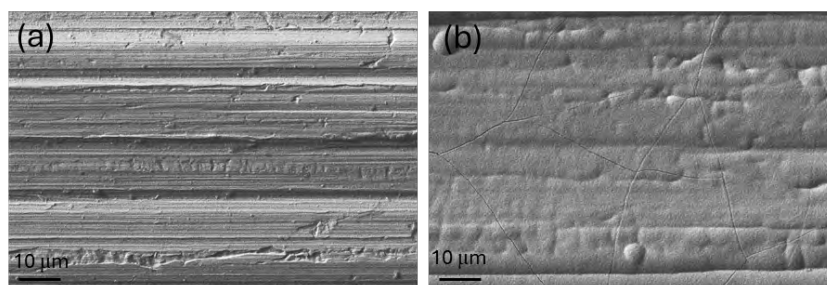


Fig. 1. SEM images of the surface before chrome plating (a), and after chrome plating (b).

Characterization of Sealing Material Behavior Under Dry Sliding Conditions for a Rotary Compressor Prototype

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Efficient sealing under dry, oil-free conditions is a key challenge in the design of rotary compressors. This contribution focuses on the tribological characterization of sealing material pairings intended for integration into a rotary compressor prototype. Tests were conducted under unlubricated sliding conditions using a self-aligning polymer sample with an average contact area of 52 mm² and a nominal pressure of 3.75 MPa. Experiments were carried out in a pressurized chamber at 90 °C and 10 bar CO₂ [1], with oscillation at 5 Hz and a stroke length of 6 mm, over a total duration of 120 minutes. The tribological performance of the selected material combinations was evaluated both quantitatively and qualitatively.

The pairing of PA6.6_PTFE-NiP provided lower coefficient of friction (average of around 0.15) compared to PK_HM-NiP (average of around 0.24), as shown in Figure 1. Differences in the wear patterns for tribological concepts were observed as well.

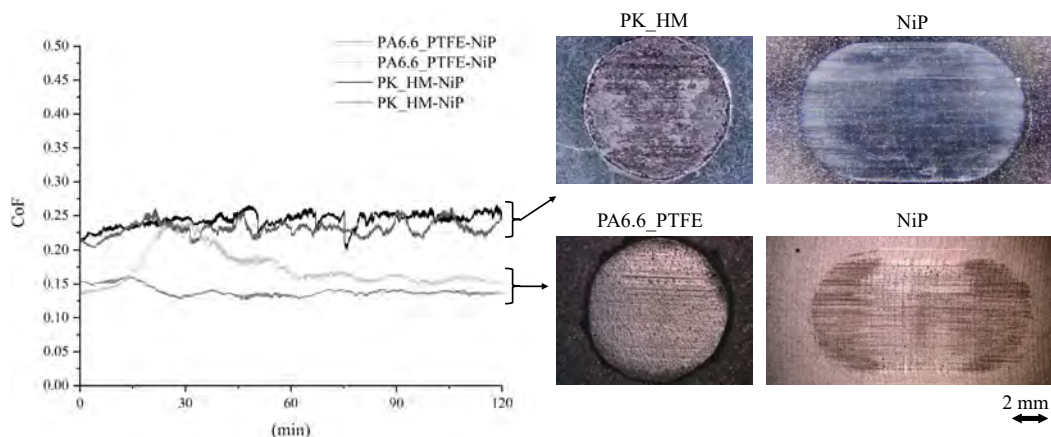


Fig. 1 Coefficient of friction vs. time for PA6.6_PTFE and PK_HM (Polyketone) samples tested against NiP coated Al6082 substrate. Wear tracks on PK_HM, PA6.6_PTFE and NiP.

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Tribological properties of selected polyhydroxyalkanoates (PHAs), a biobased and biodegradable polymers to be used as sliding materials

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Polymer sliding elements are beneficial for the environment since they do not require the use of oil or grease. Currently used polymer sliding elements are based on polymers derived from fossil fuels. Once products made from fossil-based polymers are no longer needed they become waste, which takes a very long time to decompose in the environment. In addition, fossil-based polymers are a source of microplastics entering the environment.

With these issues in mind, it is essential to look for sliding elements made from biobased and biodegradable polymers. Promising materials are polyhydroxyalkanoates (PHAs) which are produced by bacteria that consume components from various carbon feedstocks, including municipal solid waste and sewage. PHAs are biodegradable [1]. PHAs are converted by microorganisms into environmentally safe end products such as carbon dioxide, water, and compost. The biodegradation process of PHAs can occur in various environments including soil, river or sea water, and does not require special conditions such as high temperature or the presence of biomass.

As PHAs are a new concept in tribology, little information on their wear was found in the literature. Therefore, the research was conducted in order to investigate the issue. The study examined the wear of selected PHAs (PHB, P34HB, PHBH, PHBV). Moreover, the static and kinetic friction coefficients were also determined. PHAs results were compared to the results of PA6, which is a conventional (non-biodegradable) plastic often used in sliding elements.

Especially the PHB and PHBV blend had interesting tribological properties. Wear at a pressure of 3 MPa and a speed of 0.33 m/s was $32 \pm 5 \mu\text{m/km}$, which is slightly higher than $19 \pm 4 \mu\text{m/km}$ for PA6. The friction coefficient was 0.26 ± 0.02 , and for PA6 it was almost twice as high (0.5 ± 0.04). Moreover, the PHB and PHBV blend performed very well at high pressure (4 MPa) and speed (1 m/s). The friction coefficient was 0.15 ± 0.01 and wear was $43 \pm 6 \mu\text{m/km}$.

In conclusion, the study determined that biobased and biodegradable PHAs might be a suitable materials for sliding elements.

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Vibrational Characteristics of Radial Deep Groove Polymer Ball Bearing

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Polymer bearings have emerged as a viable alternative to traditional metal-based bearings in specific applications, primarily due to their self-lubricating properties [1-3]. They can be used effectively in extreme environmental conditions, are lightweight, exhibit high resistance to corrosion and chemicals, and can attain a low coefficient of friction (COF) without requiring external lubrication [4]. However, there remains a limited amount of research focused on evaluating their vibrational characteristics, which is essential for their applicability in engineering applications [5-10]. The present study investigated the vibrational characteristics of two different sizes of radial deep groove ball bearings through free run and rolling contact fatigue tests. During the free run test, a rotor was mounted on a set of bearings and subjected to minimal load for one million cycles. At the same time, vibration and RPM signals were continuously monitored. Additionally, orbit and shaft centerline plots were obtained using eddy probe sensors with the DAQ system before and after the completion of the test. The second phase involved conducting a rolling contact fatigue test to assess the dynamic performance of the bearings under varied loading conditions. The bearings were rotated for up to one million cycles, with loading increments ranging from 36 N to 108 N, applied in steps of 36 N. The findings indicate that the bearing has demonstrated excellent dynamic stability, and further research needs to be conducted to scale up its usage.

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Adhesion in Viscoelastic Sliding Contacts

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Adhesion of viscoelastic materials is a topic of utmost importance in a countless number of engineering applications, yet literature lacks a comprehensive energy-based theoretical framework to fully describe viscoelastic adhesion. Observations of phenomena such as hysteretic losses, adhesion hysteresis, and velocity-dependent adhesive strength underline the limitations of existing models, which often rely on scale separation or assume elastic behavior. We present a novel theoretical framework for viscoelastic adhesion, addressing this gap and providing a robust foundation for understanding and engineering viscoelastic materials with tailored adhesive properties. Our approach moves from the principle of virtual work to take into account for the effect of the non-conservative energy terms related to internal viscoelastic stresses in determining the contact behavior of viscoelastic materials in steady sliding against rough profiles [1,2]. This framework explains the physical origins of some peculiar phenomena observed in viscoelastic adhesion, including the velocity dependent enhancement of pull-off forces [3] and the increase in contact area [4] and friction [5] at relatively low velocity due to adhesive hysteresis. Notably, this theoretical framework extends beyond existing theories by elucidating the combined effects of bulk viscoelasticity and interfacial adhesion and can also be applied to unsteady conditions [6]. By addressing the fundamental interplay between viscoelasticity and adhesion, we establish a theoretical foundation that enables a deeper understanding of observed phenomena and guides the engineering of advanced adhesive systems.

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The role of friction and finite elasticity in wavy contacts

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From Hertz's pioneering work in 1882 to recent advancements in the field, contact mechanics has traditionally relied on the strong assumptions of linear elasticity. However, experiments involving materials that undergo large deformations, such as rubbers and elastomers, are hard to be described within this framework based on small strain and displacement, especially when frictional slip occurs. In such cases, it is essential to move beyond linear elasticity to account for geometric and material nonlinearity. Despite efforts to develop numerical tools capable of incorporating these features in contact problems, our understanding of their actual impact remains limited.

In this study, we investigate the basic case of normal contact between a wavy rigid indenter and a flat, deformable substrate. We examine the influence of finite strains and displacements, under both frictionless and frictional interfacial conditions. To this end, we developed a finite element model [1], and we compared its predictions with linear Westergaard's solution. The results indicate that even in frictionless contact scenarios, nonlinearity induce significant deviations of the contact response. This discrepancy increases with the aspect ratio of the wavy indenter increases.

More importantly, we found that the presence of friction in finite elasticity framework induces contact hysteresis in loading and unloading cycles. This offers a possible additional explanation to existing observations [2] usually ascribed to other interfacial phenomena, such as adhesion [3] and viscoelasticity [4].

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Comprehensive experimental analysis in the drilling of AISI P20 Steel

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Portugal's moulding industry is globally recognised for producing precision moulds in automotive, packaging, electronics, and medical devices. Key industrial hubs, such as Marinha Grande and Oliveira de Azeméis, are renowned for their technological innovation and skilled craftsmanship. This study investigates the dry-machining performance on AISI P20 of a conceptual carbide (WC-Co) drill-bit tool, which will perform hole-making and boring tasks simultaneously. Cutting forces (F_{cut}), vibrations and machining time (Δt) were measured to characterise the outcome from the input parameters combination, as well as the Material Removal Rate (MRR). Chip morphology and Tool-Wear (TW) were assessed by Scanning Electron Microscopy (SEM) analysis to understand the influence of a set of parameters on the wrought-stock material removal and the identification of the predominant TW mechanisms. The experimental characterisation results provided valuable insights into understanding the performance of this novel drill-bit on heat-treated steels' dry-machining, and what path to follow to improve this conceptual and novel tool. These findings are critical for supporting not only the Portuguese moulding industry but also to provide a broader and fostered knowledge for overseas moulding industry and advancing machining tool design, contributing to global the competitiveness and innovation.

Keywords: AISI P20 (DIN 1.2311), Carbide tools, Cutting Forces, Vibrations, Tool-Wear, Chip Morphology

Friction dynamics: from control theory to interleaved systems

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In my talk I will report on the application of control theory to dynamics governed by the paradigmatic rate- and state-variable law for solid-on-solid friction [1]. Several control problems are considered for the case of a slider dragged on a surface by an elastic spring. By using swift state-to-state protocols, we show how to drive the system between two arbitrary stationary states characterized by different constant sliding velocities in a given time. The derived driving protocols also allow to avoid a stick-slip instability, which instead occurs when velocity is suddenly switched. We also address the functional minimization problem of finding the optimal protocol that connects two steady states in a specified time, while minimizing the work done by the friction.

In the last part of the talk, I will also present preliminary experimental results on friction dynamics in a system of interleaved paper sheets. This system is characterized by a strong nonlinear amplification of friction, and when slowly pulled apart in a traction machine, it exhibits stick-slip motion with large force drops. I will show and discuss how the dynamical features of the stick-slip events evolve during the detachment.

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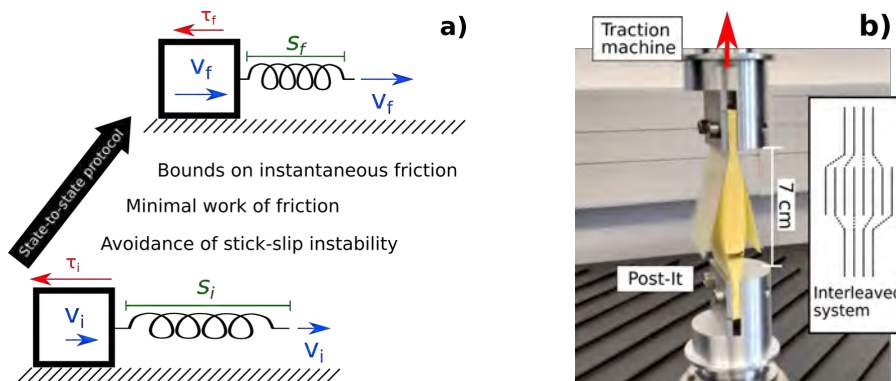


Fig. 1 a) Overview of the study on the control of friction. b) Assembly of interleaved Post-It pulled apart in a traction machine.

Friction coefficient and work function investigation of transition-metal dichalcogenide

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Despite extensive research on the tribological properties of MoS₂, the frictional characteristics and electronic properties of other members of the transition-metal dichalcogenide (TMD) family have remained relatively unexplored [1,2]. To understand the effect of the chalcogen on the tribological behavior of these materials and gain broader general insights into the factors controlling friction at the nanoscale, we compared the friction force behavior for a nanoscale single asperity sliding on MoS₂, MoSe₂, WS₂, and WSe₂, in bulk using friction force microscopy (FFM) Fig.1a. Additionally, we used Kelvin probe force microscopy (KPFM) to investigate the work function Fig.1b. All the materials were prepared and measured in a nitrogen environment.

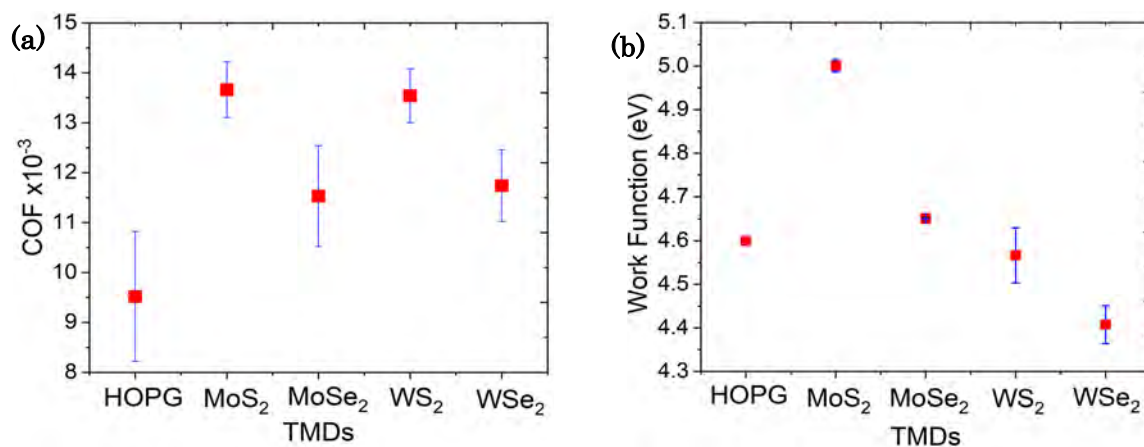


Fig. 1. Surface characteristic of TMD materials compared to HOPG. (a) Coefficient of friction (COF) and (b) work function.

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Investigation of Frictional Properties of Ionic Liquids Using Developed FM-AFM/LFM System

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Cyano-based ionic liquids are expected to be applied as lubricants due to their excellent friction-reducing performance [1]. Although this friction reduction is believed to result from the formation of an adsorbed layer of the ionic liquid on the sliding surface, the detailed mechanism remains unclear. Therefore, we developed a new AFM analysis method that combines FM-AFM and LFM, as shown in Figure 1. In this study, we selected [EMIM][DCN] (1-ethyl-3-methylimidazolium dicyanamide) as the ionic liquid and investigated the relationship between the solid-liquid interfacial structure and the frictional properties using the FM-AFM/LFM system. The measurement results are shown in Figure 2. From the observation results, a repulsive layer of approximately 0.67 nm—comparable in size to the [EMIM] cation and a [DCN] anion [2][3]—was detected.

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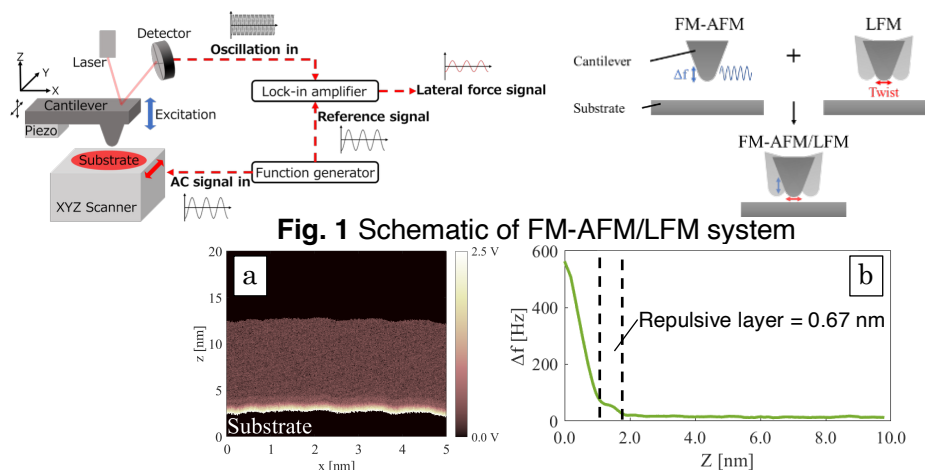


Fig. 2 (a) ZX cross-sectional image of frequency shift (Δf) and (b) force curve in ionic liquid

Friction induced Tribovoltaic studies on metal - semiconductor junction

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Diverse material couplings have been tested and classified based on their surface charge effects for Tribovoltaic applications [1]. It has been proposed that, at the interface of a p-n junction, the tribovoltaic effect is related to electron-hole pairs generated by the continuous forming and breaking of chemical bonds during sliding (Bindington effect) [2].

In this work, a reciprocating ball-on-plate module of a standard tribometer (CETR UMT-3) was implemented for the measurements. A dynamic conventional Schottky junction was obtained by sliding an Aluminum ball against a Silicon substrate (Si-Al). A low-friction ($\text{CoF} < 0.6$) and a high-friction ($\text{CoF} > 0.8$) region have been observed depending on the number of cycles, ascribed to different wear of both the counter bodies and the consequent production of debris. In both these regions, the observed electric signals are periodic, reflecting the trend of the CoF in the reciprocating motion. The highest voltage peaks observed in the high friction region is about 240 mV, while in the low friction region the peak is about 15 mV. However, in the high friction region, a threshold can be identified above which the voltage becomes extremely noisy, and spans even negative values. This unstable behavior is ascribed to extensive wear of the surfaces and transferring of material from/to the two counter bodies, observed in post – elemental analysis of the ball and the wear tracks. The EDX spectra analysis also revealed the presence of increased oxygen content, which is due to the resulting chemical reactions at the interface of the sliding surfaces.

Other mechanical couplings (Si-DLC, steel-DLC) showing a similar behavior have been studied, to help establish a better understanding of the parameters effecting the voltage generation.

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Negative Slope of the Friction-Velocity Curve in Lubricated Viscoelastic Contacts

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Friction-induced vibrations (FIVs) are often undesired incidents that can disturb the smooth operation of sliding contacts, e.g. sealings and lead screws. One of the major causes of FIVs in sliding systems is an instability between friction and velocity [1]. There, the negative slope of the friction-velocity curve can lead to arising vibrations.

The causes of this instability in the friction-velocity relation may rely on different phenomena. For lubricated systems, the Stribeck curve has a negative slope in the regime of mixed lubrication (as highlighted in Fig. 1a). Additionally, for systems involving bodies of viscoelastic material, the viscoelastic friction also inhabits a region where the instability is present (see highlighted in Fig. 1b). The velocities of the critical regions change based on phenomenon and system parameters, such as multiscale roughness.

In this work, lubricated systems including viscoelastic materials are investigated. The effects of mixed lubrication and viscoelastic friction are considered jointly. Here, flow factors are used to include the influence of the surface roughness on the fluid shearing [2]. The viscoelastic friction is determined based on the theory presented by Persson [3].

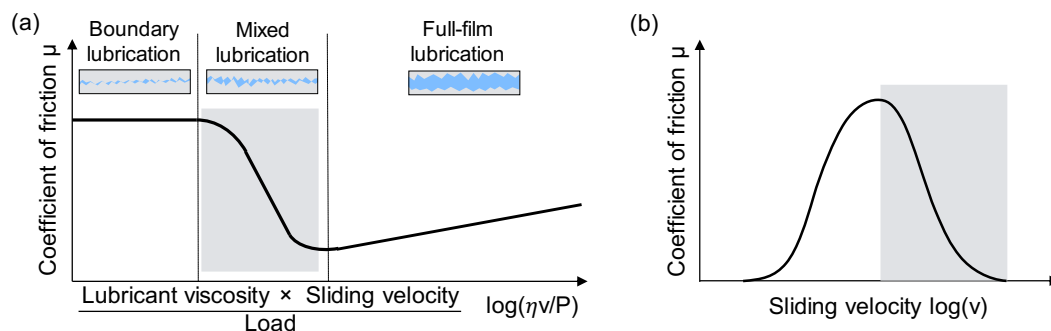


Fig. 1 Friction-velocity relations. (a) Stribeck curve. (b) Viscoelastic friction.

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New Approach in Friction analyzing and Energy Consumption in Ballroom Dance Performances

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The existing literature deals very little with the friction in ballroom dancing, which leads to insufficient knowledge about its influence on the total energy consumption. In this research authors of the paper try to determinate part of total energy consumption by calculation friction loss in foot-floor interface. Based on experimental investigation with dancing couples, taking into account dancers performances and variable coefficient of friction (Fig 1), authors show that friction loss in foot-floor interface exposed by formula [1], makes only a part of the total energy consumption. Dancer data such as mass, heart rate, age, and energy expenditure were collected during performance and machine learning techniques: decision tree, random forests, gradient boosting machines, neural networks and Adaptive Neuro Fuzzy Inference System have been applied to predict energy consumption. In addition to these methods, the optimization of the neuronal network using the Multi-Objective Algorithm was performed to improve the accuracy and reduce the complexity of the model. Discoveries in this study providing valuable information to flooring and footwear manufacturers, can also be used by choreographers, trainers and designers of robots to create more efficient movements.

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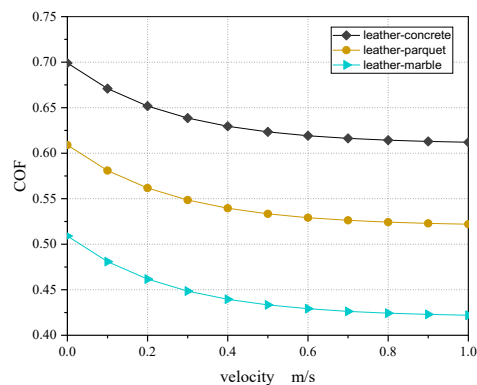


Fig. 1 COF variation on sliding velocity for most common foot-floor materials

Tuesday, 2025-07-29		HG E7		
Invited Talks	9:00-9:45	Chair: Nicholas Spencer Nuria Espallargas: Status and future prospects of Environmentally Acceptable Lubricants and green additives		
	9:45-10:30	Stefan Eder: Atomistic Insights for Engineering: Computational Pathways to Advanced Materials and Lubricant Design		
Tuesday, 2025-07-29		HG E33.5		HG F 26.3
Coffee and Posters		10:30-11:30		10:30-11:30
Sessions	Wear and Surface Damage I	Chair: Stefan Peeters	Micro/Nano II	Chair: Yurii Tsybrii
Talk 1	11:30-11:50	Mitul Solanki: Enhancing the Fatigue Life of Rolling Element Bearings by using Layered Cylindrical Hollow Rollers	11:30-11:50	Thilo Glatzel: Moiré energy dissipation driven by nonlinear dynamics
Talk 2	11:50-12:10	Xiang Chen: Full-scaling friction and wear laws of nanotwinned metals	11:50-12:10	Zhao Liu: Energy dispersion induced precisely tunable friction of graphitic interface
Talk 3	12:10-12:30	Herath Mudiyanseelage Lakshika Uresha Madhuwanthi: Erosion studies on Niobium as an alternative cladding material for neutron producing targets at ISIS	12:10-12:30	Tunc Ciftci: Hysteresis in adhesion through biasing in semiconductor surfaces
Talk 4	12:30-12:50	Ozan Sahin: Contact Separation Accelerates Atom-by-Atom Wear	12:30-12:50	Shubhang Sharma: Localized Viscoelastic Characterization of Stern Tube Seal Material Using Sinus-Mode Nanoindentation
Lunch and Posters		12:50-14:00		12:50-14:00
Sessions	Wear and Surface Damage II	Chair: Nicholas Randall	Data Analysis and Modelling III	Chair: Marco De Stefano
Talk 5	14:00-14:20	Necar Merah: Wear behavior of P110 casing material under water and oil based mud lubrication	14:00-14:20	Thomas Smit: Knocking on bearings door – a comparative study of an AE and vibration sensor to measure friction regimes in a journal bearing
Talk 6	14:20-14:40	Wataru Murakami: Surface damage of O-ring exposed to cyclic high-pressure hydrogen	14:20-14:40	Surya Kannan Peesapati: Leveraging Explainable AI for Advancements in Tribology Digitisation
Talk 7	14:40-15:00	Polychronis Dellis: A comprehensive Analysis on the Formulation and Development of Cavitation in Piston-Ring Lubrication	14:40-15:00	Tanmaya Mishra: Using an analytical model to compute the adhesive forces in pull-off force experiments with atomic force microscopy
Coffee and Posters		15:00-16:00		15:00-16:00
Sessions	Wear and Surface Damage III	Chair: Nick Garabedian	Data Analysis and Modelling IV	Chair: Mohammad Alinezhadfar
Talk 8	16:00-16:20	Yumi Hayashi: Proposal of Wear Reduction Mechanism Based on Wear Resistance Evaluation of Calcium Sulfonate-Derived Tribofilm	16:00-16:20	Michele Santeramo: A novel Boundary Element formulation for 3D adhesive contact mechanics
Talk 9	16:20-16:40	Jie Zhang: Tribological Study of Ethanol-blended Volatile Fuels in a Sealed Tribometer	16:20-16:40	Cenek Svab: Development of Efficient Optimization Algorithms for Surface Textures in Parallel Sliding Contacts
Talk 10	16:40-17:00	Boris Zhmud: Tribology of EV Transmissions	16:40-17:00	Kyotaro Matsui: Machine Learning Prediction of Friction Coefficient Using the Laser Speckle method on Directional Rough Surfaces
Apéro and Banquet in Kunsthaus 18:00-22:00				

Enhancing the Fatigue Life of Rolling Element Bearings by using Layered Cylindrical Hollow Rollers

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Fatigue life has always been an important parameter in the selection of rolling element bearings. Since its inception, researchers have tried different techniques for the improvement of the fatigue life of bearings. Hollow roller was one of the solutions for improving the fatigue life of roller type bearings. However, the thin cylindrical wall of the hollow rolling elements limits its effectiveness because of the catastrophic failures at reasonably low loading conditions. Therefore, the layered cylindrical hollow roller (LCHR) was introduced. The numerical and experimental investigation of layered cylindrical hollow roller showed higher contact width, which resulted in lower Hertzian contact stresses and possess enough strength to withstand against such catastrophic failures along with the prospect of higher fatigue life as compared to both solid and hollow roller, has been analyzed in this paper. The present paper uses the Ioannides-Harris (IH) theory model for predicting the relative fatigue life of the layered cylindrical hollow roller (LCHR) with other rollers from fatigue life criteria. The finite element package ANSYS has been used to study the stress and deformations in the loaded rollers. The simulations were carried out for solid, hollow and layered cylindrical hollow rollers under different loads and changes in the Hertzian contact stresses were observed and discussed. The simulation results assuredly favor the prospects of the higher relative fatigue life of layered cylindrical hollow roller as compared to both solid and hollow rollers.

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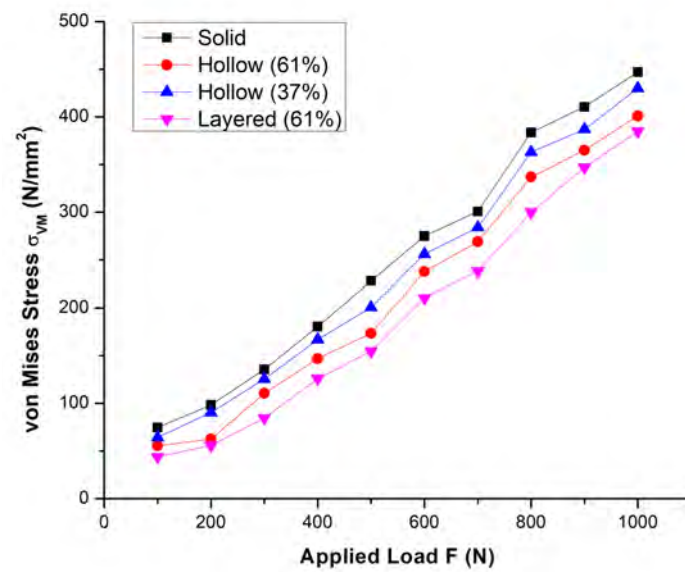


Fig. 1 The comparison of von Mises stress (N/mm²) with respect to the applied load (N) for a layered cylindrical hollow roller of 61% hollowness as compared to solid roller and two hollow rollers of 61% hollowness and 37% hollowness.

Full-scaling friction and wear laws of nanotwinned metals

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Ultrastrong nanotwinned (NT) metals hold promise for mitigating friction and wear—essential for enhancing the energy efficiency and longevity of all moving systems. However, optimizing their tribological performance has long suffered from the absence of friction and wear laws across varying tribological loading scales. Here, we have discovered full-scaling twin lamella spacing (λ)-dependent friction and wear laws in NT pure nickel and identified critical deformation mechanisms for reducing friction and wear (Fig. 1). Nano-scale friction initially increases with decreasing λ , peaking at 20 nm, and then decreases due to a transition from dislocation-twin boundary interactions to detwinning. Under micro-scale loading, friction and wear reduce linearly with decreasing λ , attributed to an unforeseen phase transition from face-centered cubic to hexagonal close-packed structures. Furthermore, under macro-scale loading, the formation of a durable oxide layer and a stable gradient nanostructure in NT nickel with λ exceeding 20 nm aids in mitigating wear loss.

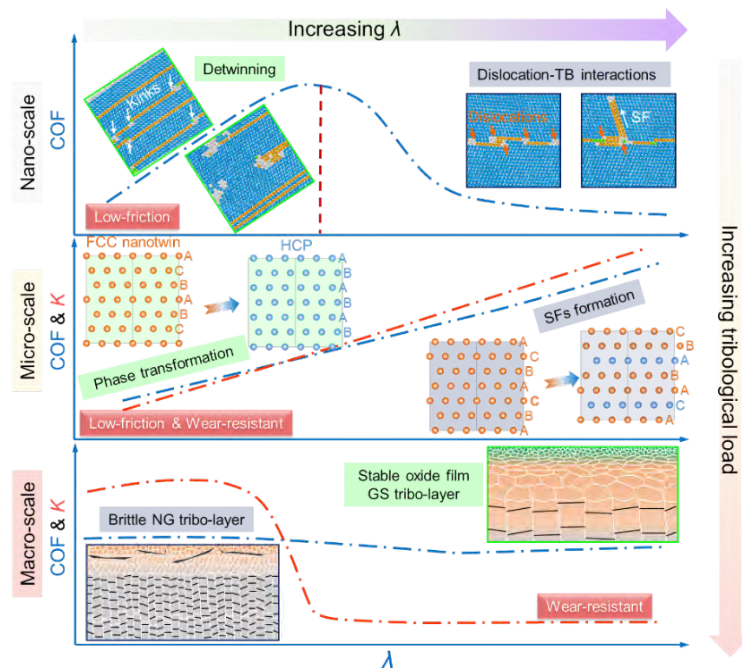


Fig. 1 Scaling laws and deformation mechanisms in NT Ni across nano-, micro-, and macro-scale frictional loading regimes as functions of λ

Erosion studies on Niobium as an alternative cladding material for neutron producing targets at ISIS

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The current design of neutron producing spallation targets (TS2) at ISIS constitutes a Tungsten (W) core clad with a thin Tantalum (Ta) sleeve. Damage due to erosion-corrosion, primarily of the Ta sleeve, is considered as one of the causes of premature failure of these targets. Due to a close match in elemental properties, Niobium (Nb) asserts itself as an alternative candidate material, however, the aqueous slurry erosion response of Niobium (Nb) is yet to be reported. This work focused on the mechanistic aspects of aqueous slurry erosion response of Nb wherein its erosion rate and mechanisms of material removal were analysed against a range of parameters such as abrasive particle (SiC) concentration, slurry velocities and impingement angle with the help of an impinging jet erosion-corrosion apparatus. Cavitation Erosion (CE) experiments were also performed to extend the general understanding of erosion response. The results revealed a peak in erosion rate at slurry impingement angle of 30°, at a slurry velocity of 6 ms⁻¹ and under abrasive particle concentration of 7 wt.%. At shallow impact angles (impact angle of 30°), ploughing and micro-cutting of plastically deformed materials due to the sharp edges of the erodent particles dominated the wear mechanism. Whereas formation of lips/ platelets around the indentation craters and their breakage due to a “plastic deformation-fatigue” cycle from the repeated erodent impacts constituted the dominant material removal mechanism. These results are consistent with those typically reported for most ductile metals. In cavitating conditions grain boundary sliding and fatigue cracking (inter and transgranular) of plastically deformed and work hardened grains was evident.

Contact Separation Accelerates Atom-by-Atom Wear

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Diamond wear can occur through various mechanisms, including covalent bond induced atom-by-atom wear [1]. While the shear stress exerted during sliding is thought to drive such attrition wear, less is known about the importance of tensile stresses for the atomic scale diamond wear process. This study aims to explore the significance of contact separation for atomistic wear. We investigate the effect of stroke length on wear behavior for ball-on-flat interfaces. Since each stroke is made on a previously untouched part of the Si_3N_4 substrate, variation in friction indirectly reveals wear of the slider (ball). Our results demonstrate that shorter strokes, which involve more frequent contact breaking, lead to faster wear. We hypothesize that sliding promotes chemical bonding across the interface while the subsequent pulling-off enhances wear.

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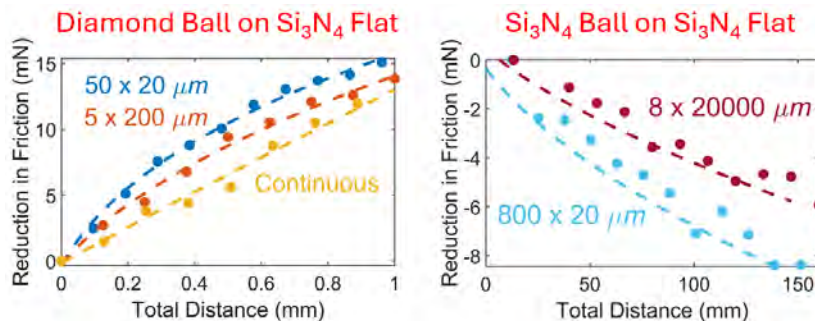


Fig. 1 Reduction in friction as a function of total sliding distance for various stroke lengths. Diamond crystallites experience ploughing friction on Si_3N_4 while self-mated Si_3N_4 displays adhesive friction. In both systems atom-by-atom wear is accelerated by pull-off.

Wear behavior of P110 casing material under water and oil based mud lubrication

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Abstract:

The present study investigates the wear behavior of two casing material P110 under different operational conditions encountered during oil and gas drilling operations. The study focuses on how rotational speed, contact load, and lubrication conditions (water-based mud (WBM) and oil-based mud (OBM)) influence the wear behavior of these materials. The experiments were carried out on a specially designed set-up, at various contact loads (1000 N, 1200 N, and 1400 N) and rotational speeds (115 RPM, 154 RPM, and 207 RPM). The designed setup which uses real drill pipe joints (DP-TJ) and casings is employed to investigate the combined effects of the lubrication type, contact load and speed on the casing wear factor and wear mechanisms.

As shown in Figure 1, the wear factors (K) obtained under WBM are almost twice as high as those under OBM for all contact loads and rotational speeds. This difference in performance is mainly due to the higher viscosity of OBM as compared to that of WBM. The analysis of these results showed that the wear factor increases linearly with the contact load for all speeds and type of lubricant. The increase of K with the contact load is due to the increase of contact pressure between the drill pipe joint and the casing. SEM analysis of worn surfaces revealed that the predominant mechanisms for both WBM and OBM were abrasive and adhesive wear.

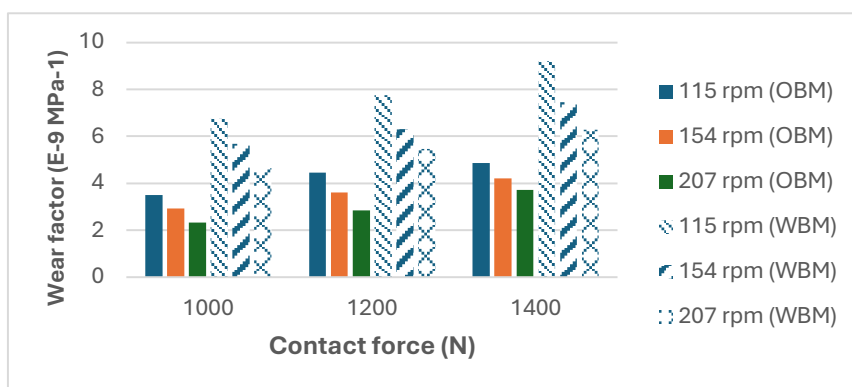


Fig. 1 Wear factor variation with contact force and speed for OBM and WBM lubrication.

Surface damage of O-ring exposed to cyclic high-pressure hydrogen

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Fuel cell vehicles, which are anticipated to be the next generation of automobiles, require the storage of hydrogen at high pressures to achieve an adequate cruising range, and rubber seals are employed in the components that handles high-pressure hydrogen. Repeated exposure of rubber materials to high-pressure hydrogen causes various types of damage due to dissolution of hydrogen [1]. However, the effect of O-ring installation parameters on this kind of damage has not been clarified.

In this study, the O-rings were repeatedly exposed to high-pressure hydrogen. The test conditions are shown in Table 1, modeling the conditions at actual hydrogen stations. The wear of O-ring surfaces was evaluated by observing their appearance using an optical microscope. The surface roughness, S_a , was measured from the 3-dimensional shape obtained using a laser microscope.

Figure 1 shows the samples' appearance after the exposure test. Blisters and abrasion marks were observed on the surface, the degree of which varied with the conditions. Greased samples showed less wear and the width was wider than the dried samples. Fig. 2 shows the surface roughness under each installation condition. It was found that the surface roughness, S_a , decreased by the application of grease. From these results, the slip of the O-ring during the repeated exposure test was discussed.

Table 1 Test condirions

Hydrogen exposure conditions	
Temperature	- 40 °C
Pressure	0.6 ± 90 MPaG
Cycle num.	30,000
O-ring material & installation conditions	
Material	Silicon rubber
Compression	20 %, 30 %
O-ring groove roughness	Ra 1.6 µm, Ra 3.2 µm
Lubrication	Dry, With greased

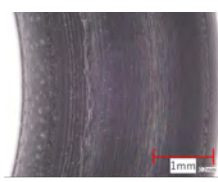


Fig. 1-1 Dry

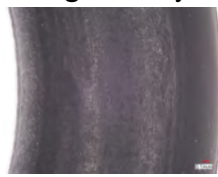


Fig. 1-2 Greased

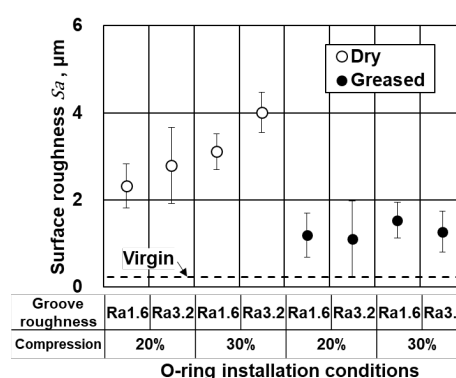


Fig. 2 Surface Roughness

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Acknowledgments

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A comprehensive Analysis on the Formulation and Development of Cavitation in Piston-Ring Lubrication

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As the phenomenon of cavitation degrades the lubrication performance, tribological characteristics, friction and wear in piston ring lubrication, research studies that combine parametric measurements, the implementation of novel techniques and visualisation to capture its initiation and development throughout the stroke, are considered factors that can establish an operating window to satisfy effective lubrication and minimise any accompanying risks.

Previous studies have focused on establishing a simplified lubrication mechanism with modelling of the lubricant flow [1,2]. Tools such as the single-ring simulating test rig can give a good insight of the lubricating conditions at the ring-liner interface while necessary modifications had updated the experimental apparatus and provided the path to implement additional measurement techniques to the engine rigs respectively [2]. It was argued that cavities initiation dynamics were demonstrated in images showing time dependent initiation of cavitation, with shapes varying initially from ferns to developed striations at mid-stroke [3]. On the engine side, visualisation techniques, in both motored and firing engines were utilised to assess lubricant properties and oil transport. Meanwhile, they provided a comparison tool between the results in the well-established simplified rig and the various engine setups [4].

The visualisation techniques proved to be robust and following the implementation of a transparent liner in the test rig, images taken from motored engines were plentiful with a focus on oil transport [4]. Then, different operating conditions were tested to enhance the aspects of lubricant optimization.

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Proposal of Wear Reduction Mechanism Based on Wear Resistance Evaluation of Calcium Sulfonate-Derived Tribofilm

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Lubricating oils play a critical role in industrial machinery by reducing friction and mitigating wear at sliding interfaces. These oils incorporate various additives that engage in complex chemical interactions, which may be either synergistic or competitive [1]; however, the underlying mechanisms remain insufficiently understood. The present study investigates the influence of calcium sulfonate rust inhibitors on the wear resistance and tribofilm formation of lubricants containing ZnDTP and MoDTC. Friction tests demonstrated that the addition of calcium sulfonate enhanced wear resistance while preserving the low-friction characteristics of ZnDTP and MoDTC. Nanoscale analyses further confirmed that calcium sulfonate facilitated the formation of tribofilms with increased thickness and density. Surface characterization revealed that the tribofilms formed in the presence of calcium sulfonate contained calcium compounds in their upper layers, contributing to smoother and more uniform structures. These findings underscore the synergistic effects of calcium sulfonate with ZnDTP and MoDTC, offering valuable insights into the optimization of additive formulations to improve lubricant performance and prolong the operational lifespan of industrial machinery.

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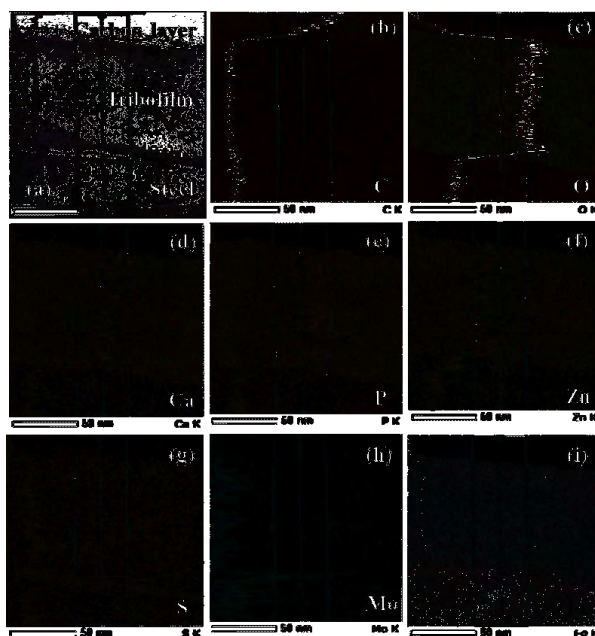


Fig. 1 (a) Scanning transmission electron microscope image and (b–i) energy dispersive X-ray spectroscopy maps and cross-sectional scans of the tribofilm

Tribological Study of Ethanol-blended Volatile Fuels in a Sealed Tribometer

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Much of the gasoline available at the forecourt in developed countries is now a blend of gasoline with between 5% and 85% anhydrous ethanol by volume (E5 to E85). The main motivation for this is to reduce fossil fuel consumption and thus net CO₂ emissions, but the ethanol present also boosts octane ratings enabling reduction in fuel aromatic content, and allows more complete combustion of the fuel. One important question that arises when using ethanol in gasoline is the impact of this relatively polar component on the response of fuel additives. The influence of ethanol on tribological performance has not been thoroughly studied, especially at elevated temperatures, because conventional lubricity tests struggle with volatile fuels due to evaporation-induced composition changes. However, a fully-sealed, high pressure tribometer (HPR) has recently become available that can study the tribological properties of volatile fuels at up to 150°C. In the current work this is used to evaluate the response of lubricity additives in ethanol-blended fuels at elevated temperatures via friction/wear measurements and wear track chemical analysis. This presentation then explores the underlying mechanism of additive performance, aiming at optimizing formulations for improved fuel injection equipment durability and efficiency.

Tribology of EV Transmissions

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EV motors and transmissions operate at high speeds and handle high power densities, placing heavy demands on bearings, seals, and gears.

TEHD and mesh-less CFD simulations open new ways to the design and optimization of lubrication and thermal management solutions for EV transmissions and e-axes. Properly parametrized CAE models can provide valuable insights into the effects of different lubricant properties on cooling and lubrication efficiencies, thereby helping in matching the lubricant and hardware characteristics for optimal performance.

In the present communication, we demonstrate the effects of different lubricants and surface finishing technologies on the tribology of high-speed gears using tribological tests and simulations. Important roles of lubricity additives and surface finish optimization are highlighted in conjunction with a move towards ultralow viscosity fluids.

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Moiré energy dissipation driven by nonlinear dynamics

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The moiré superlattice in twisted van der Waals heterostructures is of central importance for the modulation of the electronic and optical properties of the system, yet the mechanical dissipation of such moiré systems remains largely unexplored. Here, we report the experimental observations of energy dissipation across both vertical and lateral directions along the moiré superstructures, revealing a significant increase in dissipation at moiré ridges compared to flat domains. Comparison of the measurements with a theoretical phononic dissipation model suggests that the local increase in energy dissipation originates from nonlinear instability dynamics of the moiré superstructure. Criteria for such moiré energy dissipation are established, which are expected to be broadly applicable to other van der Waals heterostructures. Our results extend the understanding of mechanical energy loss in moiré systems and pave the way for the rational design of new slidtronic and twisttronic devices and nanoelectromechanical systems in general.

Energy dispersion induced precisely tunable friction of graphitic interface

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Precise control of friction at the nanoscale is crucial for developing efficient micro/nanoelectromechanical systems [1]. We demonstrate a novel approach to manipulate friction in two-dimensional materials using coupled direct current (DC) and alternating current (AC) electric fields. By applying a low-amplitude AC bias superimposed on a DC electric field, we achieve continuous reduction in friction force on monolayer graphene without compensating the DC bias [2], while preserving the integrity of graphitic interfaces [3]. Our theoretical analysis reveals a previously unrecognized energy dissipation mechanism: the vertical resonance absorbs a significant portion of the horizontal dissipation energy, reducing the sliding friction and enhancing the interfacial durability. These findings not only overcome the limitations of conventional electrically controlled friction methods for precise manipulation of micro/nano-devices but also provide novel insights into the underlying mechanisms of frictional behavior and energy dissipation processes.

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Hysteresis in adhesion through biasing in semiconductor surfaces

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Adhesion plays a critical role in semiconductor manufacturing, influencing the precision and lifespan of components such as wafer stages (Fig. 1a) [1]. Although electrical biasing is commonly used to eliminate floating potentials and enable electrostatic clamping between asperities (Fig. 1b), adhesion often persists after grounding, leading to hysteresis effects that remain poorly understood. Using atomic force microscopy (Fig. 1c) [2], we simplify complex multi-asperity mechanisms to investigate the underlying causes of electric field-induced adhesion hysteresis at the single-asperity interface between an n-type AFM tip and a p-type silicon surface under low humidity ($\sim 10\%$) (Fig. 1d). We identify electric field-induced water adsorption as the primary mechanism behind the observed hysteresis. Our results show that even sub-minute biasing produces lasting effects on adhesion, offering new insights into its control and implications for friction and wear in nanoscale systems.

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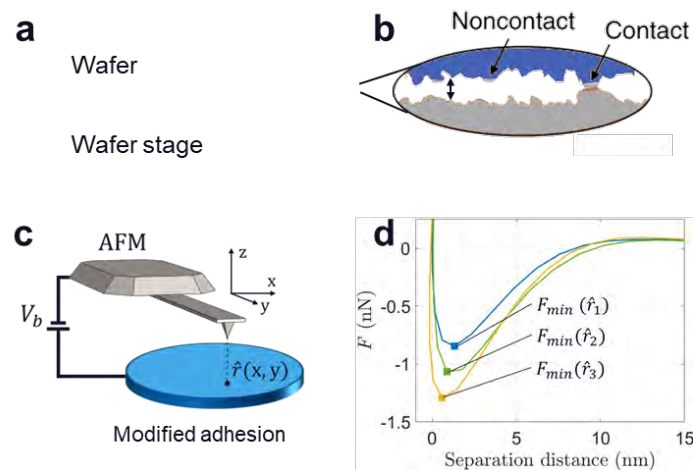


Fig. 1 (a) Schematic of a wafer and wafer stage. (b) Asperities in or near contact. (c) Atomic force microscopy setup used to investigate (d) adhesion hysteresis after applying a bias between the tip and the sample under tunable relative humidity.

Localized Viscoelastic Characterization of Stern Tube Seal Material Using Sinus-Mode Nanoindentation

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During operation, stern tube seals operate under multiple loads, i. e., speed, pressure, lubricant-material interaction, and elevated temperature leading to heterogeneous internal loads [1]. These internal loads cause degradation of the seal which may lead to local variations of the mechanical properties of the seal material (fluorocarbon rubber).

Reliable operation and lifespan of the dynamic seals depends on the pressure distribution formed in the seal-shaft contact, as well as the formation of a lubricating film. Changed mechanical properties may influence the lubrication mechanisms. Current predictions of seal performance are based on models of new seals [1].

To understand how degradation changes the performance of a seal, an analysis of degraded seals is necessary. To correctly model degraded seals, geometrical changes (wear) as well as mechanical changes need to be taken into account. Thus, locally resolved mechanical properties need to be determined. This study presents a novel approach for quantifying local mechanical properties of the seal bulk material. By using sinus-mode nanoindentation the local viscoelastic properties can be determined.

The approach enables high-resolution mapping of storage and loss moduli at different frequencies. To validate the nanoindentation results, complementary frequency sweep tests were conducted on sample elastomers using Dynamic Mechanical Analysis (DMA).

The analysis based on the Standard Linear Solid (SLS) model provided insights into key viscoelastic parameters, including the relaxed modulus and characteristic relaxation/retardation times. The findings enable the integration of local viscoelastic properties into finite element modeling (FEM), thus, helping understand how localized degradation influences the lubrication mechanisms.

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Knocking on bearings door – a comparative study of an AE and vibration sensor to measure friction regimes in a journal bearing

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Condition monitoring systems based on acoustic emissions are of ever-increasing importance, however most are based on costly sensor systems. In this contribution a comparison of purpose-build acoustic emission (AE) sensor with parallel measurements of a repurposed automotive knock sensor are presented. With the final goal of classification of friction regions within Stribeck curves based on acoustic emissions from journal bearings.

For this purpose, a setup was devised that contains two moveable bearing shells with a common rotating shaft, each equipped with either a purpose-build AE sensor or a repurposed knock sensor to measure and capture AE emission within the respective ranges of the sensors (100 to 900 kHz or 3 to 25kHz respectively). The journal bearing test rig was further equipped with a loadcell for normal forces, a friction force loadcell, and equipment to measure the electrical resistance of the contact. All equipment was connected to one central data capturing device, this setup enabled not only a 2 MSa/s capture rate of the AE-signals but also parallel capturing of the previously mentioned measurements at a rate of 4 kSa/s.

Figure 1 shows some of the preliminary findings. A Stribeck plot is created using the previously described measurements. It is evident that high-friction events, such as boundary lubrication at low rotational velocity, may be recorded, and that the amplitude of the signal decreases as friction decreases.

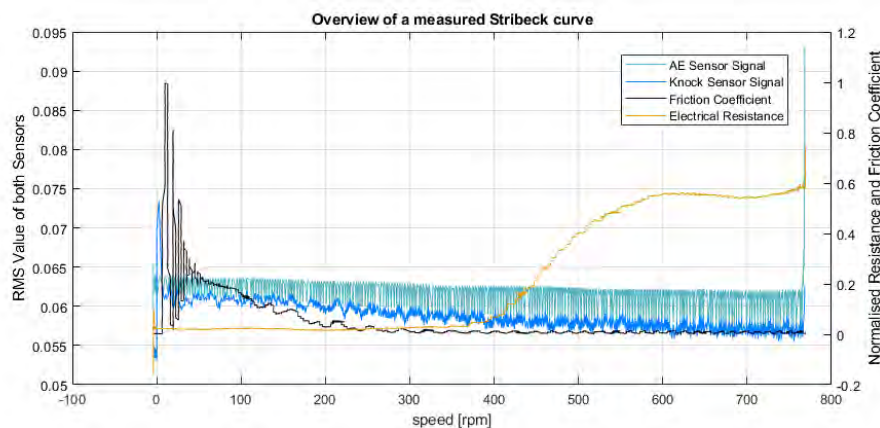


Fig. 1 Stribeck curve with AE sensor signal, knock sensor signal, and the electrical resistance

Leveraging Explainable AI for Advancements in Tribology Digitisation

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Machine learning (ML) and explainable artificial intelligence (XAI) may alter the landscape of what is conceivable, moving beyond the basic study of processes and toward the creation of unique and/or potentially clever tribological systems. As the quantitative survey from Marian et al. [1]. shows, ML has already been used in various sectors of tribology, ranging from composite materials and motor technology to manufacturing. Peesapati et al. [2] presented mode decomposition techniques combining with ML and feature vectors, giving a novel way to predict periodic wear phenomena on rolls. This study aims to provide a supplementary tool for efficiently producing optimal designs beyond the reach of current physiologically justified formulations, rather than creating indisputable prediction models.

The developed XAI model predicts the failure frequencies of an entire machine utilising any sensor data as input, regardless of whether the failure is due to chatters, housing, or bearings. Through the use of a white box, the model also examines the trade-offs between accuracy, robustness, transparency, and explainability.

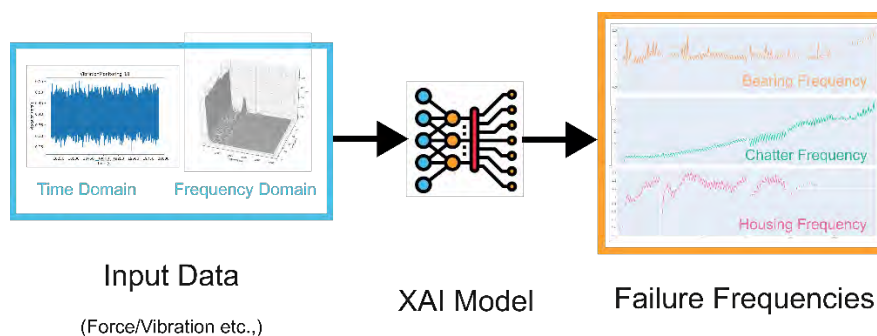


Fig. 1 Overview of the XAI model classifying the frequencies

Acknowledgments

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Using an analytical model to compute the adhesive forces in pull-off force experiments with atomic force microscopy

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Estimating the contribution of the capillary meniscus to adhesion is critical to understand slip in the interfaces such as wafer and wafer stage in lithography and granular systems such as soil and fault-gouges which result in landslides and earthquakes respectively. Pull-off forces have been measured during unloading and separation of the probe from the substrate, using Atomic Force Microscopy (AFM). The results are used to estimate adhesive forces in presence of adsorbed liquid in the interface due to capillary effects.

However, pull-off force measurements do not inform about the relative contributions such as surface tension, meniscus and viscous forces. Typically, the pull-off force measured for interfaces with liquid layers has been directly related to the meniscus force. Since the meniscus geometry during separation varies from its initial geometry during static contact, and is therefore different at the moment of pull off, the meniscus force directly estimated from pull-off measurements can be inaccurate.

Therefore, in our research we have applied and extended an analytical model to calculate all components of adhesive forces during separation of liquid-mediated contacts to estimate pull-off forces. We have further validated the force-displacement curves obtained from the model with the pull-off plots obtained from our AFM experiments using a spherical silica probe contacting different substrates. Using this model we can explain the effects of ambient and operating conditions such as relative humidity RH, dwell time t_d and separation rate v_s on the initial meniscus geometry and therefore their effect on the pull-off force measured using AFM.

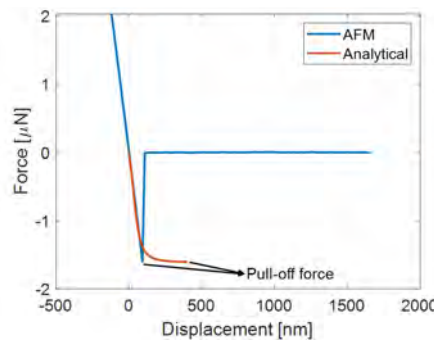


Figure 1. Comparison of pull-off forces obtained from the AFM and the analytical model using a 5 μm dia., silica probe on a silica sheet at 2 μN load, 75% RH, $t_d = 1$ s and $v_s = 10$ $\mu\text{m/s}$.

A novel Boundary Element formulation for 3D adhesive contact mechanics

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The pivotal role of surface roughness in mechanics and in the industrial panorama is indubitable, especially when adhesive interactions are present. In the recent decades, such a complex relation has triggered the interest of the scientific community, leading to analytical theories [1] and numerical approaches [2,3], which enhanced the comprehension of the phenomena involved, and blazed the trail to new studies and applications. Specifically, the numerical strategies developed to investigate adhesive contacts pave over the definition of a specific potential modelling the adhesive interaction, thus requiring the definition of a specific set of parameters. However, such a definition is quite arbitrary, and a slightly different set of parameters may result in a very distinct shape of the potential, that is, a very dissimilar adhesive behavior.

Thus, we present an energy-based Boundary Element method to assess 3D adhesive contacts, which does not require the knowledge of any interaction potential, but just the introduction of the work of adhesion. In particular, the methodology retrieves the real contact area by minimizing, for a fixed value of indentation, the total potential energy. This is obtained by an efficient topographical strategy aimed at optimizing a 3D contact pattern. Incidentally, the methodology is general, able to deal with both smooth and rough surfaces and, most importantly, is flexible, as it is not restricted to the adhesive case, but it can be deployed to analyze a wide range of applications characterized by different surface energy contributions.

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Development of Efficient Optimization Algorithms for Surface Textures in Parallel Sliding Contacts

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Surface texturing can reduce friction and increase load-carrying capacity (LCC), but its effectiveness largely depends on contact type and operating conditions. While numerical optimization offers a systematic approach to design optimal textures, its high complexity and computational cost remain a major challenge. Addressing this limitation is crucial for the practical implementation of optimized surface textures in engineering applications.

In this study, a new optimization algorithm is developed that iteratively refines surface textures. At each step, the algorithm generates possible texture variations, evaluates their performance based on LCC, and selects the best configuration for the next iteration. This process continues until no further improvements are found. Simulations are performed using Reynold's equation with Jakobsson-Floberg-Olsson (JFO) cavitation conditions. Each evaluation runs independently via parallel processing, accelerating the optimization process.

The proposed algorithm outperformed up-to-date Genetic algorithms (GA) and Monte Carlo (MC) methods, converging to the same optimal texture with fewer simulations and achieving a 5–10x speedup. It was tested on various texture shapes, proving its adaptability.

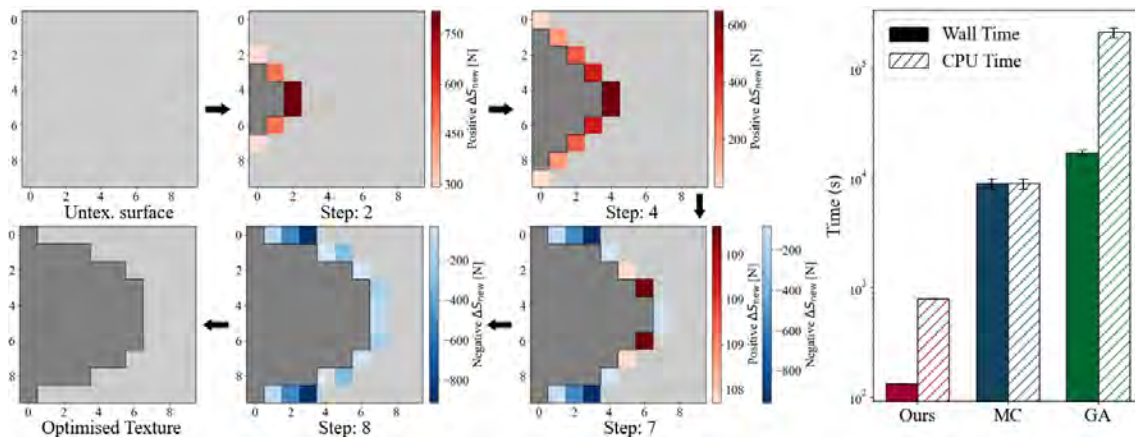


Fig. 1 Algorithm optimization progression (left), comprising with other algorithms (right).

Acknowledgments

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Machine Learning Prediction of Friction Coefficient Using the Laser Speckle method on Directional Rough Surfaces

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As the demand for higher-quality machine components increases, methods for analyzing friction behavior of operating machines have been developed. Recently, the laser speckle method, which enables non-contact surface measurements, has attracted attention. Several studies have proposed predicting the friction coefficient from speckle patterns using machine learning techniques [1].

It is also well known that the directionality of surface roughness affects frictional characteristics, with groove orientation being a particularly important factor [2]. However, the effects of continuously varying surface roughness orientation on both speckle patterns and friction coefficients have not been thoroughly investigated.

This study aims to analyze changes in friction behavior and speckle patterns caused by continuous variation in groove orientation and to improve the accuracy of friction coefficient prediction using machine learning.

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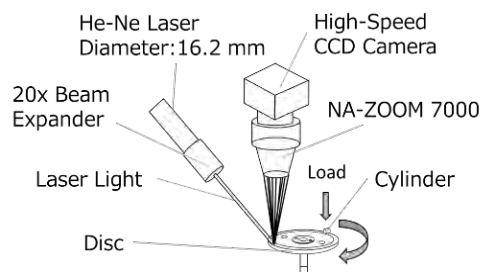


Fig. 1 Test equipment overview

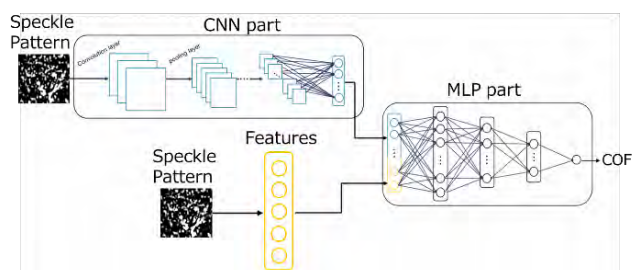


Fig. 2 CNN-MLP hybrid model

Wednesday, 2025-07-30		HG E7		HG E5	
Invited Talks	9:00-9:45 9:45-10:30	Chair: Emanuel Tack Rosa Espinosa: Soft Tribology Lars Pastewka: How multi-scale roughness affects contact, friction and adhesion			
Coffee	10:30-11:30			10:30-11:30	
Sessions		Chair: Emanuel Tack		Chair: Cenek Svab	
Talk 1	Polymer Tribology II 11:30-11:50	Hayate Saito: Influence of Sliding Paths and Temperature on Wear of PTFE Composites		11:30-11:50	Boris Brodmann: Topography as an Energy State:A Hamiltonian Perspective on Surface Roughness
Talk 2	11:50-12:10	Carmine Putignano: How does viscoelasticity determine the tribology of polymer bearings?		11:50-12:10	Shivaprakash N. Ramakrishna: The Influence of Surface Roughness and Chemistry on Nanoscale Friction: Sliding vs Rolling
Talk 3	12:10-12:30	Shouyi Yin: PTFE Tribology in Cryogenic Conditions		12:10-12:30	Harsh Kumar: Effect of Surface Topography Parameters on the Electric Contact Resistance in a Lubricated Contact
Talk 4	12:30-12:50	Manoj K. Maurya: Mechanical and Tribological Properties of Cross-Linked Polymer Networks		12:30-12:50	Yao Xu: Effect of Designed Surface Textures on the Tribological Behavior of Additively Manufactured PEEK Nanocomposite Sliding Layers
Lunch	12:50-14:00			12:50-14:00	
Sessions		Chair: Guillermo Morales		Chair: Matthias Freisinger	
Talk 5	Polymer Tribology III 14:00-14:20	Yoshinori Sawae: Influence of trace moisture content on friction and wear of PTFE composites with different fillers in high-purity hydrogen gas		14:00-14:20	Mark Kuzman: Asperity interactions and the real contact area in multi-asperity contacts
Talk 6	14:20-14:40	Hikaru Okubo: Multimodal observation for friction-induced layered structures of polymer brushes		14:20-14:40	Nicholas Randall: In-situ Extreme Micromechanics for Tribology Applications
Coffee	14:40-15:40			14:40-15:40	
Wednesday, 2025-07-30		HG E7			
Final Words	15:40-16:10	Farewell, and next meeting			

Influence of Sliding Paths and Temperature on Wear of PTFE Composites

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Recently, the operating environment for sliding materials has become more severe due to the increased performance of industrial equipment. The wear of resin composites is affected by the ambient atmosphere and sliding conditions. However, the mechanisms of the effects of the ambient atmosphere and sliding conditions on the wear of resin composites have not been clarified. The purpose of this study was to clarify the mechanism of how sliding paths and temperature affect the wear of PTFE-based composites.

PTFE composites containing carbon fiber, bronze and molybdenum disulfide were used in the friction test. The sliding path was linear reciprocating motion and circular motion, and the surface temperature of the specimens was room temperature ($25^{\circ}\text{C} \pm 2^{\circ}\text{C}$) and 120°C .

Fig. 1 shows the specific wear rate of the PTFE composites under each condition. The specific wear rates during the second friction period (sliding distance of 5~10 km) were lower than those of the first friction period (sliding distance of 0~5 km). The wear increased significantly under the 120°C circular motion condition compared to the other conditions. In this presentation, we will introduce the wear mechanism of each condition through morphological and chemical analysis.

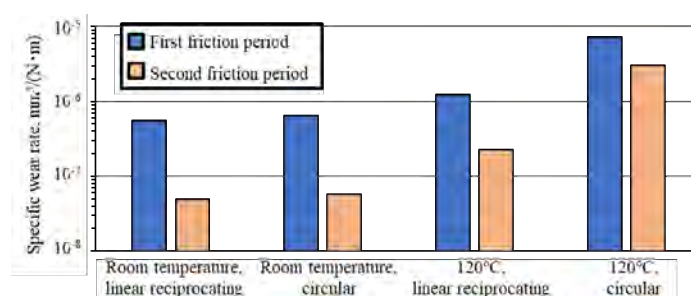


Fig. 1 Specific wear rate of PTFE composites for each sliding path and temperature.

How does viscoelasticity determine the tribology of polymer bearings?

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The complex rheology of viscoelastic materials has attracted significant interest in both academia and industry, leading to the development of analytical and numerical methodologies to better understand viscoelastic dissipation in various biological and mechanical applications [1]. In this work, we present a novel steady-state Boundary Element (BE) methodology for analyzing conformal and non-conformal contact problems under dry and lubricated conditions [2], with a particular focus on industrially relevant components in rotordynamics: rolling element bearings and journal bearings.

First, we investigate a rolling element bearing with polymeric raceways and rigid rollers, revealing that contact conditions are highly dependent on the excitation frequency. Unlike in purely elastic cases, some rollers in the load zone lose contact with the rings under specific conditions. To validate our numerical approach, we compare resisting torque predictions for a polymer-based bearing against experimental data at varying temperatures and loads, demonstrating strong agreement.

Then, the lubricated contact problem of a polymer journal bearing is analyzed: different contact configurations are considered, namely soft-on-hard (soft shaft and rigid bearing liner), hard-on-soft (rigid shaft and soft bearing liner), and soft-on-soft (both the shaft and the bearing liner are soft), showing that such visco-elastohydrodynamic lubricated problem is not solely governed by the Hersey number, but the definition of additional parameters taking into account the complex rheology of the interacting solids material is required. Finally, experimental tests on a Polyamide 6 (PA6) journal bearing at different temperatures and loads show promising preliminary agreement with numerical predictions.

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PTFE Tribology in Cryogenic Conditions

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Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer with low friction and excellent chemical resistance, making it ideal for tribological applications such as bearings, seals, gaskets, and coatings [1]. Due to the development of aerospace technology, lubrication under cryogenic conditions is increasingly needed [2]. With the applications of satellites, space-operated instruments, and ultra-cold high-energy density liquid bumps, fluid lubrication has been critically restrained by unsuitable pour points of most lubricants. Fortunately, PTFE as an excellent self-lubricating material with a wide temperature range, works well at even extremely low temperatures. Given this, PTFE is extremely important for cryogenic tribological applications.

Despite PTFE's long history in tribological applications, studies under cryogenic conditions remain limited. There is still many research area worth exploring. In this work, a comprehensive tribological study was conducted over a temperature range from 50°C to -180°C. The results revealed a correlation between PTFE's tribological performance and its mechanical properties (obtained from DMA experiments), indicating that the lubrication mechanism at cryogenic temperatures may differ significantly from that at room temperature and is strongly influenced by how the relaxation of PTFE depends on temperature. In addition, this work investigated the temperature-dependent wear modes of PTFE through surface characterization techniques such as SEM and confocal microscopy. Furthermore, chemical analysis, including XPS and FTIR, were employed to elucidate the underlying tribochemical mechanisms responsible for the observed changes in tribological performance. Additionally, considering the impact of low-temperature media in practical applications, we explored the differences in transfer film formation between liquid and gaseous environments.

In this presentation, we summarized the tribological mechanisms of PTFE, focusing on the effects of temperature and different media at cryogenic temperatures. This work will shed light on the working mechanism of polymer tribology at cryogenic conditions, which will be crucial for aerospace technology.

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Mechanical and Tribological Properties of Cross-Linked Polymer Networks

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Mechanical and tribological properties play a crucial role in the design of soft materials, such as polymers, as they directly impact their performance and functionality across a wide range of applications. Key mechanical properties, such as stiffness and elastic modulus, define the material's resistance to deformation, while tribological properties, including the friction coefficient, are essential for understanding its behavior under load. Crosslinking is an essential mechanism for tuning polymer properties. Crosslinked polymers exhibit high strength, lightweight characteristics [1], and self-healing capabilities due to their microstructural arrangements. The degree of crosslinking can range from weakly crosslinked elastomers to highly crosslinked epoxies [2-3].

In this study, we conduct a computational investigation of crosslinked polymer (CP) networks using molecular dynamics simulations, employing an indentation technique with explicit indenters. The indentation technique is commonly employed to measure elastic modulus and stiffness via force-distance curves [4]. Additionally, we explore the structural characteristics and evaluate the coefficient of friction as a function of crosslinking bond density in polymer networks. We establish a relationship between force-depth response and local bond-breaking in CP networks. The findings indicate that an increased monomer fraction leads to enhanced material stiffness [5] and a reduced friction coefficient. Moreover, an increase in indentation depth leads to higher friction forces.

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Influence of trace moisture content on friction and wear of PTFE composites with different fillers in high-purity hydrogen gas

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Hydrogen is expected to be a clean and renewable energy carrier in future decarbonized society. To use hydrogen as a fuel for a fuel cell vehicle (FCV), the purity of hydrogen must be maintained during transportation and storage since FCVs need extremely pure hydrogen to avoid fuel cell poisoning. Therefore, the use of volatile lubricating oils and greases is strictly forbidden for machine components in FCVs and a hydrogen refueling station (HRS), and polymer composites with excellent self-lubrication ability are widely used as tribo-materials in sliding interfaces [1]. In addition, the amount of residual water is strictly regulated to be less than 5 ppm in the related ISO standard [2]. However, influence of such an extremely dry gas environment on friction and wear of polymer composites has not been reported yet.

In this study, a custom-made pin-on-disk type tribometer installed in a high-vacuum chamber was used to examine influence of trace moisture content of hydrogen gas on friction and wear of polytetrafluoroethylene (PTFE) composites sliding against a metal counterface in high-purity hydrogen gas environment. The chamber comprised a specially designed moisture controller to regulate the trace moisture content of hydrogen gas at ppm level. By using this equipment, the water content of hydrogen gas environment could be adjusted from 40 ppm to less than 1 ppm during the sliding test [3]. Carbon fiber (CF) and polyphenylene sulfide (PPS) were chosen as filler materials for reinforcing PTFE, and results were compared between PTFE composites containing each filler.

Results indicated that the influence of trace moisture content was completely different for CF-filled PTFE and PPS-filled PTFE. The friction and wear of CF-filled PTFE increased with increasing the water content, while PPS-filled PTFE showed the lowest wear for the lowest water content and almost constant friction regardless of the amount of water. Counter surface analyses after the sliding tests suggested that trace moisture content affected the carbon transfer in case CF-filled PTFE and the metal fluoride formation in case PPS-filled PTFE.

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Multimodal observation for friction-induced layered structures of polymer brushes

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Abstract

Polymer brushes are a type of soft polymeric coating used to control surface and interfacial properties. It is well known that their design has been inspired by biological sliding systems—such as the human knee joint—which consist of brush-like soft materials that are both durable and low-friction. In fact, polymer brushes have attracted significant attention from tribological researchers and engineers due to their ability to provide extremely low friction coefficients ($\mu < 0.01$) at microscopic tribological contacts.

In recent decades, a breakthrough technology for synthesizing thick and dense polymer brushes—referred to as concentrated polymer brushes (CPBs)—has been developed. CPBs exhibit a thickness of several microns in their swollen state, resulting in significantly reduced friction and markedly enhanced durability in macroscopic tribological contacts compared to conventional semi-dilute polymer brushes. This exceptional performance is attributed to the dense packing and extended chain conformation of polymers within CPBs, which provides robust load-bearing capacity and effective lubrication. As a result, CPBs hold promising potential for advanced tribological applications, such as mechanical seals and bearings. However, CPBs do not yet possess sufficient durability to meet the performance requirements under severe sliding conditions. Therefore, enhancing the durability of CPBs requires a deeper understanding of their lubrication mechanisms.

Several studies have suggested that the layered structure of CPBs plays a critical role in their lubrication and wear behavior. Miyazaki et al. identified two layers in swollen PMMA-CPBs—a surface-diluted layer and a bulk-concentrated layer—based on nanoindentation measurements [1]. Vlădescu et al. also reported that the outermost layer of PMMA-CPBs behaves in a "liquid-like" manner under sliding conditions, indicating a dilute structure [2]. Additionally, surface force apparatus (SFA) measurements have been used to explore the mechanical responses of PMMA-CPBs at the solid-liquid interface [3]. Our previous research using a custom-built SFA identified four boundaries corresponding to three distinct layers within the CPB: concentrated, middle, and dilute layers [3]. The SFA further revealed that the layered structure evolves during sliding, influencing the friction and wear behavior of the CPB/steel tribopair. While these findings highlight the importance of the layered structure in

wear processes, the specific roles of each layer remain unclear.

In this study, the relationship between the layered structure and wear behavior of CPBs was investigated. To elucidate the details of the solid–liquid interface, we developed an SFA-based multimodal measurement system (see **Fig. 1**) capable of simultaneously monitoring static and dynamic mechanical responses, interfacial thickness, and molecular characteristics (e.g., concentration, strain, crystallinity, orientation) at the solid–liquid interface. Using this system, multimodal compression tests were performed to characterize the relationship between the mechanical behavior, molecular information, and interfacial thickness of CPBs.

From the results of the compression tests, distinct boundaries within the interfacial thickness of the CPBs were identified. These boundaries were characterized by specific mechanical responses and changes in molecular concentration under compression (see **Fig. 2**). Based on these results, the CPB structure was described in terms of five layers: solvent layer, dilute layer, semi-dilute layer, middle layer, and concentrated layer. In the presentation, we will report on the friction-induced structural evolution of these layers and discuss their respective roles in wear behavior.

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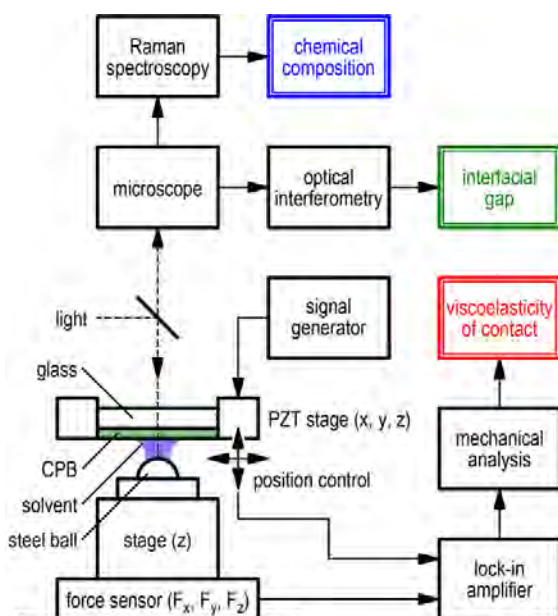


Fig. 1 Schematic of the SFA

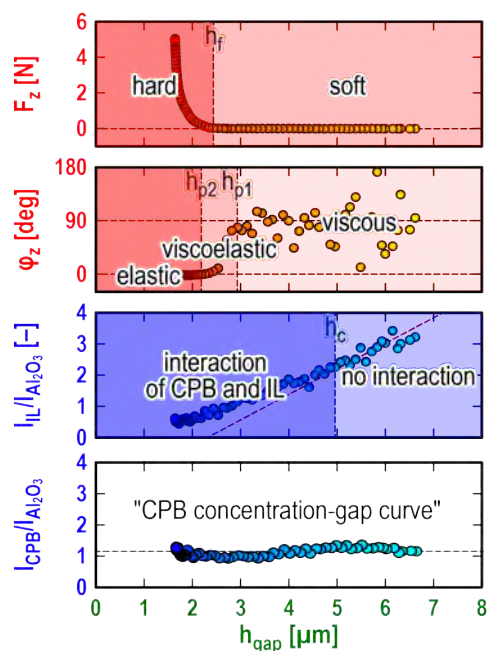


Fig. 2 Compression test results

Topography as an Energy State: A Hamiltonian Perspective on Surface Roughness

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In this lecture, we introduce a new approach to characterizing the roughness of friction partners in tribological systems. We show that tribologically induced topographical changes can be framed in a thermodynamic context, allowing topography to be understood as a dynamic statistical ensemble. From phenomenological thermodynamics, we derive that surface fractality is a fundamental property of condensed matter, enabling an independent energetic analysis. Geometrical considerations show that fractal microgeometry can be described on any scale through the existence of a smallest representable wavelength in the form of a Hamiltonian. This makes it an energetic property independent of the bulks elemental composition. We combine the strengths of power spectral density (PSD) and amplitude density function (ADF), that are used in both, theoretical and applied tribology. These independent statistical properties yield a symplectic form via measure theory, allowing topography to be represented as a phase space density. The resulting bivariate density distribution can be interpreted as the wave function of topography, providing new insights into the dynamics of tribological systems. We apply this model to a twin-disc test rig and the evolutionary changes of counter surfaces in sealing systems, integrating optical methods for quantification.

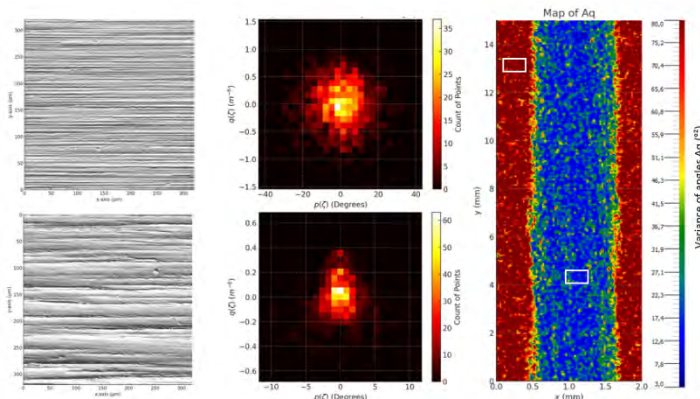


Fig. 1: Topography images of the initial and running in surface; middle: Phase space density of the topographical ensembles; right: colour map of the local Gradient variations of the reference sample measured by a scatter o meter

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The Influence of Surface Roughness and Chemistry on Nanoscale Friction: Sliding vs Rolling.

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Surface roughness and surface chemistry play crucial roles in contact interactions, significantly influencing adhesion and frictional behavior. This influence becomes even more pronounced in nanoscale systems, such as micro/nano-electromechanical systems (MEMS/NEMS), where surface forces dominate due to the high surface-to-volume ratio. We investigate the effects of surface roughness and chemistry on adhesion, friction, and contact mechanics at the nanoscale for both sliding and rolling contacts using colloidal probe atomic force microscopy (CP-AFM). Our results reveal that in sliding friction, nanoscale roughness can alter contact mechanics due to changes in contact area, local deformation, and adhesive interactions [1,2]. Meanwhile, surface chemistry, tailored through polymer brushes, impacts friction through variations in brush thickness and grafting density. The lateral deformability of these grafted chains during sliding directly influences their frictional and contact mechanical behavior [3]. Furthermore, we examine the effects of surface roughness and chemistry on rolling contacts at the nanoscale using our custom-modified AFM probe [4,5].

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Effect of Surface Topography Parameters on the Electric Contact Resistance in a Lubricated Contact

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Electric vehicles are essential to the worldwide transition to sustainability, with technological advancements and favorable policies fueling market expansion. The electric motor is a vital component of their reliability, with bearings playing a crucial role. However, rolling element bearings encounter challenges such as wear and electrically-induced damage caused by bearing currents. These currents generate electrical contact resistance (ECR), resulting in discharges that lead to damage and early failure. These damages are significantly impacted by the surface topography of the contacting surfaces. Therefore, to gain deeper insight, it is essential to examine how surface topography influences ECR. This paper investigates the influence of surface topography parameters, such as RMS roughness, skewness, and kurtosis, on ECR in lubricated contacts. It also highlights the role of the film thickness ratio (Λ) on lubrication regime transitions and its effect on ECR, with ECR increasing as the regime shifts from boundary to elastohydrodynamic lubrication. It is observed that surface roughness is a key factor, with rougher surfaces maintaining better electrical conductivity, while smoother surfaces exhibit higher ECR, particularly at higher speeds. The results highlight the importance of optimizing surface topography to minimize ECR in lubricated mechanical systems.

Keywords: Electric contact resistance, Surface topography, Lubricated contacts

Effect of Designed Surface Textures on the Tribological Behavior of Additively Manufactured PEEK Nanocomposite Sliding Layers

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Additive manufacturing (AM) offers high flexibility to design intricate surface structures in a single process, enabling lightweight solutions while optimizing tribological performance. Among AM techniques, fused filament fabrication (FFF) provides a cost-effective solution for creating tailored surface patterns. This study investigates the tribological behavior of fused filament fabricated polymer surfaces with porous structures (cf. Figure), emphasizing the dual goal of weight reduction and wear performance optimization under varying normal force-sliding velocity conditions (F_N -v-levels). Porous sliding layers were fabricated with controlled pore size and distribution, and their tribological performance was evaluated using a plate-on-ring tribometer.

The results demonstrate that porous surfaces achieve significant weight reduction while maintaining competitive tribological properties. Under low F_N -v-levels, porous surfaces exhibit higher wear rates due to debris accumulation within the pores, enhancing abrasive wear. Conversely, at high F_N -v-levels, the filled pores act as reservoirs for wear debris, forming a protective film that reduces wear. The wear rate of porous surfaces correlates with F_N -v-levels, indicating a transition from abrasive to lubricative mechanisms. Key tribological mechanisms include debris capture, pore filling, nanoparticle release, and the formation of protective transfer films. Additionally, the geometric characteristics of the pores, such as size and distribution, significantly influence the tribological response, providing a pathway for optimizing surface designs for specific operating conditions. These findings highlight the potential of additive manufactured porous designs to balance weight reduction and wear resistance. The study underscores the importance of optimizing pore geometry for achieving superior tribological performance in lightweight, additively manufactured components.



Asperity interactions and the real contact area in multi-asperity contacts

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Knowledge of the real contact area, where surfaces actually make contact at the asperity level, is crucial for understanding contact mechanics, influencing contact design, tribological performance, and product lifetime. While numerous theoretical models exist for real contact area estimation, experimental validation remains insufficient, particularly regarding the influence of asperity interactions. This study aims to get better understanding and provide experimental insights into multi-asperity contacts. We developed an experimental approach for in-situ observation of the real contact area with submicron resolution. Using advanced optical methods developed in-house, we directly measure asperity interactions under varying load conditions. Steel samples with hardness ranging from 220 HV to 850 HV and surface roughness values in range between $R_a = 0.1 \mu\text{m}$ and $R_a = 1.0 \mu\text{m}$ were pressed against a sapphire window until reaching their yield strength. The results revealed that asperities progressively merge as the load increases, emphasizing the critical role of asperity interactions in the real contact area. This phenomenon is significant even at low loads, and provides valuable insights for improving statistical models of asperity interactions and real contact area estimation. A deeper understanding of asperity interactions is essential for improving theoretical models and enhancing real-world applications of contact mechanics. Our findings highlight the need for further experimental studies to validate and improve existing real contact area models.

Keywords: real contact area, multi-asperity, submicron scale, asperity interactions

In-situ Extreme Micromechanics for Tribology Applications

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Nanomechanical testing has evolved beyond basic measurements of hardness and elastic modulus to include a wide array of mechanical properties such as strain rate sensitivity, stress relaxation, creep, fracture toughness, coating adhesion, coefficient of friction, and tribology, facilitated by focused ion beam milled geometries. Recent innovations, such as high cycle fatigue testing, have broadened the scope of properties that can be examined at the micro and nanoscale. However, these techniques are challenging due to issues like low oscillation frequencies, prolonged test durations, and significant thermal drift when using standard indentation instruments.

Novel piezo-based nanoindentation methods have emerged, enabling access to extremely high strain rates ($>10^4$ /s) and high oscillation frequencies (up to 10 kHz). Traditionally, high strain rate testing of materials at rates between ~ 100 /s and $10,000$ /s was achievable only with macroscale. At the microscale, strain rates have typically been constrained to ~ 0.1 /s or lower due to limitations in instrumentation, insufficient data acquisition rates, and elastic wave propagation issues during testing.

This presentation will highlight recent advancements in instrumentation for in-situ in SEM extreme mechanics testing at the micro and nanoscales. A particular focus will be on a versatile testing platform capable of conducting both linear and pin-on-disk tribological testing and strain rate testing over a range of 0.0001 /s to $10,000$ /s (spanning eight orders of magnitude) with high-speed actuation and sensing capabilities, offering nanometer and micronewton resolution.

We will also address the complexities of performing extreme mechanics tests across a broad range of extreme environments, including nuclear, cryogenic, and high-temperature conditions, with a temperature range from -150°C to over 1000°C . The discussion will cover the challenges of variable temperature tests, associated technological advancements, and protocol improvements, illustrated with select case studies. The inherent benefits of using small sample volumes will be discussed alongside the related instrumentation, technique development, data analysis methodologies, and experimental protocols. We will present examples of test data where a wide range of strain rates has been combined with variable temperatures to investigate the effects of strain rate as a function of temperature. Finally, we will explore future research directions in this evolving sub-field of micromechanics.

Wednesday, 2025-07-30		HG E7		
Invited Talks	9:00-9:45 9:45-10:30	Chair: Emanuel Tack Rosa Espinosa: Soft Tribology Lars Pastewka: How multi-scale roughness affects contact, friction and adhesion		
Wednesday, 2025-07-30		HG E33.1	HG E33.3	
Coffee	10:30-11:30		10:30-11:30	
Sessions		Chair: TBA		Chair: Anna Igual
Talk 1	Ecological Advances I 11:30-11:50	Atsushi Iijima: Adsorption characteristics of various adsorbents on degraded substances in oil for reuse of used lubricants	Greases 11:30-11:50	Rowena Crockett: Friction Management at the wheel-rail contact
Talk 2	11:50-12:10	Arun Kumar: Tribological and Rheological Insights into the Lubrication Potential of Eco-Friendly Thixotropic Silica Gels	11:50-12:10	Hiroshi Tani: Conductivity Improvement of Conductive Grease with Added Polyphenyl ether
Talk 3	12:10-12:30	R. Gnanamoorthy: Surface Design and Contact Characteristics of 3D Printed Polymer Insulation Shields for EV Bearing Applications	12:10-12:30	Hanul Chun: The relationship between differences in thickener structures and the oil separation of grease
Talk 4	12:30-12:50	Yun Zhao: Lubricant behaviours in electrified tribology	12:30-12:50	Dominika Senajova: Evolution of friction with ageing of gamma-irradiated commercial greases in contact with a steel substrate
Lunch	12:50-14:00		12:50-14:00	
Sessions				Chair: Vasily Rublev
Talk 5	14:00-14:20		Biotribology IV 14:00-14:20	Lukas Odehnal: Additively Manufactured Ti6Al4V with Controlled Surface Structure: Long-Term Wear Performance and Durability
Talk 6	14:20-14:40		14:20-14:40	Mengyuan Li: Feasibility of using non-destructive techniques for measuring tooth degradation
Coffee	14:40-15:40		14:40-15:40	
Wednesday, 2025-07-30		HG E7		
Final Words	15:40-16:10	Farewell, and next meeting		

Adsorption characteristics of various adsorbents on degraded substances in oil for reuse of used lubricants

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In recent years, countries and companies have been working to develop technologies for the reuse and recycling of products and materials, with the aim of realizing a circular economy society. We focused on lubricants, which is reused as fuel in Japan for about 90% of the collected materials [1]. The adsorption and filtration method is a common method for reusing lubricants, but there is a lack of knowledge for improving quality and processing with high efficiency. Therefore, in this study, we verified the adsorption effect using multiple degraded oil types with the aim of obtaining guidelines for selecting an adsorbent for each oil type.

The adsorbents used were commercially available. The adsorption process was carried out by adding 5 wt% of the adsorbent to the used lubricants and stirring it for 30 minutes at room temperature. The treated lubricants was analyzed by JIS K2501, using the total acid number as a representative indicator of degradation.

Fig. 1 shows the relationship between the specific surface area of the adsorbent and the total acid number of used mineral oil, which had the highest correlation with the total acid number and other parameters such as the particle diameter and pH of the adsorbent. As the specific surface area of the adsorbent increased, the total acid number decreased, indicating a trend of increasing acid removal capacity. The presentation will also report on the effects and issues of different types of oil.

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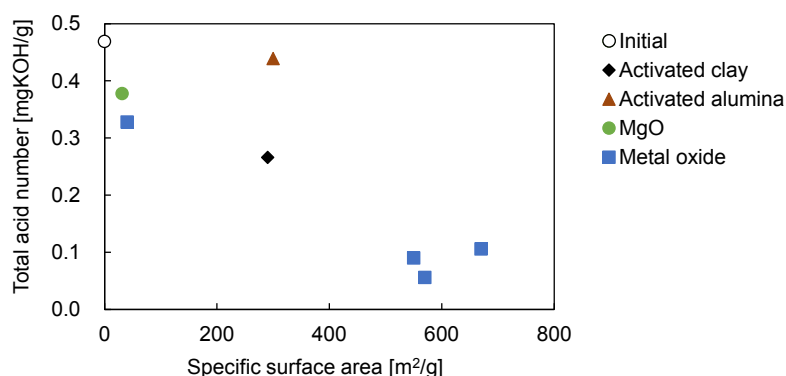


Fig. 1 Relationship between the specific surface area of the adsorbents and the total acid

Tribological and Rheological Insights into the Lubrication Potential of Eco-Friendly Thixotropic Silica Gels

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Toxicity from conventional oil and grease lubricants can be mitigated by introducing water-based lubricants with improved rheological properties. We present a thixotropic colloidal gel of silica nanoparticles formed in the presence of NaCl. Our experiments demonstrate that the tribological performance of the formulated gel can be optimized by tuning its rheological properties. We achieved an optimal combination of super-low friction and negligible wear using a thixotropic and chemically robust gel formed through van der Waals interaction between the flocs which provides self-repairing properties and continuous tribo-film formation. These attributes enable the gel to maintain and regain its structure during periods of inactivity, while also forming a thin film with sufficiently low viscosity to slip into the interfacial contact zone and continuously replenish it with lubricant.

Surface Design and Contact Characteristics of 3D Printed Polymer Insulation Shields for EV Bearing Applications

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Electric vehicle traction motor bearings fail early due to combined electrical and mechanical loads. The magnitude and frequency of the current that flows through the bearing depend on the motor type and electronic controls used for speed control. The presence of the electrical current results in an early rise in contact temperature due to the Joule heating, in addition to the frictional heating, which causes lubricant degradation [1,2]. This study explores a novel approach to minimizing the current flowing into the bearing by incorporating a polymer shield on the outer race. The shields on the outer race will encounter fretting damage, and it is necessary to understand the fretting characteristics of the polymer used using simplified experiments. The surface morphology affects the contact characteristics, and different surface designs are easily fabricable in polymers using advanced additive manufacturing processes. Polyphenylene sulfide (PPS), a high-temperature polymer, is considered in this study due to its technical and economic advantages compared with other engineering polymers. Attempts were made to fabricate different surface patterns on the PPS polymer fabricated using fused filament fabrication-based additive manufacturing. Layer orientation is one important parameter and is investigated in detail.

Fretting behaviour of 3D-printed PPS samples with different surface features when fretted against aluminium alloy (preferred material for motor casing) was studied using the in-house built test device. Tests were conducted at a constant slip amplitude and with different normal loads. The fretting friction coefficient variation with time is found to vary during the initial cycles due to the different deformation mechanisms of the contacting layers. Debris accumulation varies depending on the surface pattern and affects the fretting properties. The fretting loops and fretting surfaces were observed, and fretting wear mechanisms are reported.

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Lubricant behaviours in electrified tribology

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With the advancement of electrification, nearly every aspect of society is now connected to electricity. When electricity is applied to lubricated engineering components, they operate under current and voltage conditions. This presents new challenges for lubricants, as they require stable working conditions and are sensitive to environmental changes. In this oral presentation, we present the progress, challenges, and perspectives of lubricants under electric conditions. First, we highlight the importance of understanding triboelectro-physical and -chemical mechanisms in electrified tribology. Then, we present how lubricants change under electric conditions at the molecular, interfacial, and electrochemical levels and how these changes affect tribological performance. Finally, we show current challenges from experimental, theoretical, and engineering perspectives and strategies for accelerating the development for electrified tribology.

Tribological Performance of Palm Oil-based Grease with Nanoparticle Additives

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The environmental impact of mineral greases is a growing concern. While their benefits are well known, their toxicity and depletion drive the search for eco-friendly alternatives [1]. Vegetable oils have gained significant attention as a viable alternative due to their biodegradable and renewable properties [1]. Palm olein, in particular, has long fatty acid chains and polar groups that naturally adhere to metal surfaces, providing strong interactions with the lubricated surfaces [2,3]. The addition of the additive may form a protective layer on the contacting surfaces [4]. In this study, the green lubricant was formulated using palm olein as a base oil in grease formulation. The tribological test was performed using a four-ball tribometer to compare the characteristics of the formulated grease with commercial mineral grease. The performance of the greases was then further evaluated using a roller bearing test rig. Findings in Fig. 1 indicate that the palm oil-based grease formulated with a lithium thickener initially exhibits low performance. However, incorporating nanoparticle additives significantly improves its performance, reducing friction and minimizing wear.

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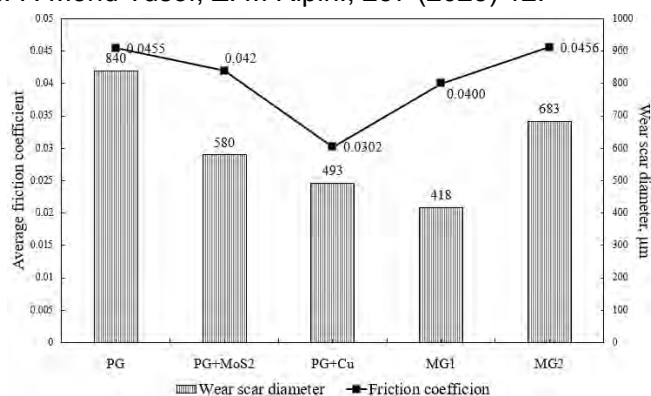


Fig. 1 Average friction coefficient and wear scar diameter of the greases.

Conductivity Improvement of Conductive Grease with Added Polyphenyl ether

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Electrical pitting is one of the most common types of damage observed in rolling bearings used in inverter-driven motors. To prevent electrical pitting, it is crucial to ground the rotating shaft or use ceramic bearings as insulation. Conductive greases containing conductive materials such as carbon black or others have been developed as alternatives. However, shaft grounding and ceramic bearings are expensive. Moreover, conductive grease with carbon black or similar materials may become susceptible to electrical pitting over time as the conductive material gradually separates from the base oil or agglomerates, leading to an increase in the bearing resistance despite the initially low values. In this study, we experimentally investigated the electrical discharge characteristics of polyphenyl ether (PPE) oil and found that it generated graphite-like carbon (GLC). The experimental setup and observed phenomena are shown in Fig. 1. Based on this finding, we hypothesized that adding PPE to conventional conductive grease would maintain conductivity over an extended period owing to the formation of GLC. To verify this hypothesis, we evaluated rolling bearings lubricated with PPE-enhanced conductive grease using an electrical pitting test. The addition of PPE effectively stabilized the conductivity of grease over time, suggesting its potential for prolonged protection against electrical pitting.

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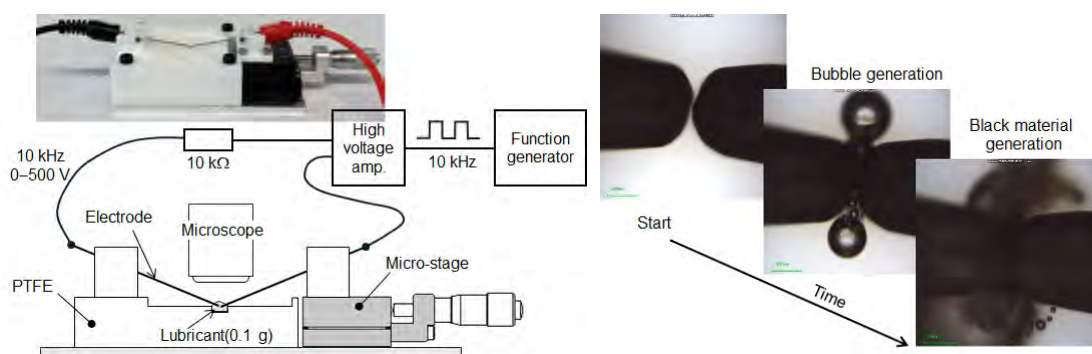


Fig. 1 Observation of discharge in lubricant oils and observed phenomena.

The relationship between differences in thickener structures and the oil separation of grease

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Grease is a semi-solid lubricant with base oil, additives, and thickeners. In conventional grease analysis, the thickener structure has been ignored and treated as a homogenized fluid due to the difficulty of obtaining the thickener structure and insufficient computer performance[1]. Recently, however, significant progress in observation techniques and computers has enabled us to overcome these problems. As a first step, the three-dimensional structure of thickener from washed grease was obtained by using Focused ion Beam-Scanning Electron Microscope (FiB-SEM). Additionally, as shown in Fig. 1, a grease model incorporating the thickener structure was constructed.

In this study, the effects of thickener fiber length and structure on grease oil separation characteristics were investigated, and the experimental results were compared with those of simulation analysis. By controlling the cooling speed of 12-hydroxy stearic acid lithium grease, sample greases with different thickener fiber lengths and structures were prepared, and oil separation tests for each grease were conducted using a swing rotor-type centrifuge.

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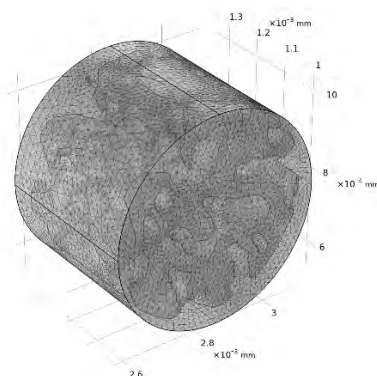


Fig. 1 Grease model with thickener structure

Evolution of friction with ageing of gamma-irradiated commercial greases in contact with a steel substrate

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Successful operation of the CERN accelerator complex relies on numerous mechanical devices with lubricated components exposed to radiation doses of 0.1-40 MGy over their lifetime [1]. Many components operate intermittently, with motion frequency ranging from a few cycles/day to a few cycles/year, otherwise they remain static under load. Maintenance access is severely restricted due to high residual dose rates and lubricants must provide initial low-friction motion to ensure smooth component operation. Previous studies [1,2] reported degradation of conventional lubricants in the 0.1-1 MGy range, with few products stable beyond 10 MGy, but there is very little data on the tribological properties.

The project studied the effects of gamma-irradiation (up to 10 MGy) on the properties of several greases with different chemistries of base oils (polyphenyl ether, hydrocarbon, fluorocarbon) and thickeners (silica, bentonite, Li soap, polyurea, PTFE). Post-irradiation analysis included rheology, chemical (FTIR, Raman) and tribological tests, with a focus on initial friction at low sliding speed and small displacement. To mimic component inactivity and assess substrate corrosion, grease films were aged (0-12 months) on a steel disc before friction testing. Initial friction results for the zero-aged samples showed all fresh greases gave similar $\mu \sim 0.1-0.15$. However, with increased radiation dose the results diverged and very high, unstable friction (up to $\mu \sim 0.5$) was measured for some compositions. The aged-film results also showed increased friction with time for some greases and in some cases, surface corrosion. The friction results correlate with supporting analyses which showed different degradation mechanisms including base oil cross-linking (mainly hydrocarbons), formation of oxidation/acid species (fluorocarbon, hydrocarbon), thickener loss (Li-soap, polyurea), organophosphorus additive loss, and changes of physical properties (oil separation and/or hardening). The study shows the differences in lubricant radiation resistance, failure mechanisms, and the need for test protocols based on operational conditions.

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Additively Manufactured Ti6Al4V with Controlled Surface Structure: Long-Term Wear Performance and Durability

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The current generation of implants is not yet fully optimized, often requiring early revision. Additive manufacturing (AM) has emerged as a key production technology, including joint replacements, offering benefits such as implant individualization and design simplification. However, to effectively integrate AM, it is essential to investigate the material tribological behavior, as the conventionally manufactured Ti6Al4V has shown limitations [1].

This study examines the tribological performance of 3D-printed implants through experiments on a pin-on-plate tribometer equipped with a fluorescence microscopy module and a long-term wear simulator under in vivo-like conditions. The tested materials included CoCrMo and 3D-printed Ti6Al4V with a controlled surface structure, paired with UHMWPE or PMMA counterparts. Key parameters evaluated were the friction coefficient, synovial fluid (SF) constituent retention in the contact area, and wear rate (using optical profilometer).

Results indicated a higher and more stable presence of SF constituents in the contact area, enhancing lubrication film stability. The friction coefficient was slightly higher due to surface structures. Initially, the wear rate of AM Ti6Al4V was higher at shorter sliding distances, but after 400 meters, the trend reversed, outperforming conventional CoCrMo.

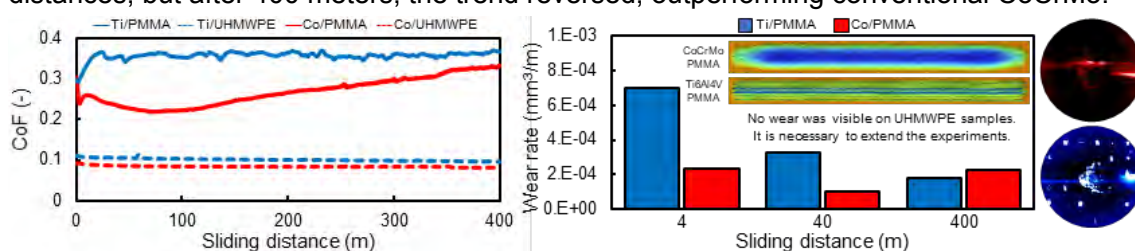


Fig. 1 Friction coefficient (left), Wear rate (middle), Illustrative image of contact area (right).

References

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Acknowledgments

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Feasibility of using non-destructive techniques for measuring tooth degradation

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Dental degradation is a chronic degenerative disease and cannot be avoided. This study aims to verify the possibility of using non-destructive and radiation-free techniques to detect and measure the changes to teeth geometry from wear.

Optical coherence tomography (OCT), ultrasound and focus-variation microscopy (Alicona) were used to measure the wear loss of samples in this research. A Universal Mechanical Tester (UMT) was used to create wear scars on the samples by two types of wear modes with variable test cycles (see Fig. 1).

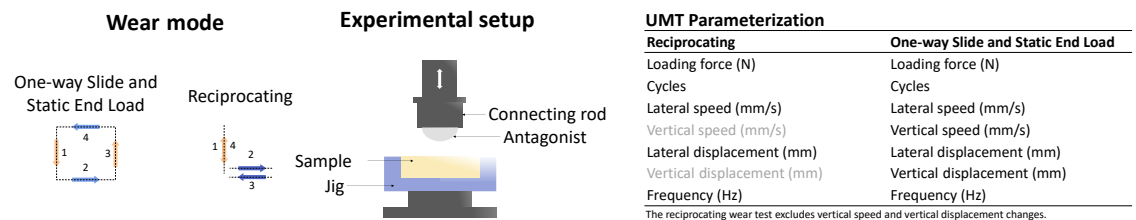


Fig. 1 Schematic illustration (not drawn to scale) and parameterization of wear test.

The results of the depth of scars detected by all the above measurement techniques in an aluminium block and flat layer artificial restorative material specimens (Vita Enamic and Fibrafill® CUBE) that were used to mimic a tooth and worn in artificial saliva using an antagonist (zirconia balls) are shown in Fig. 2.

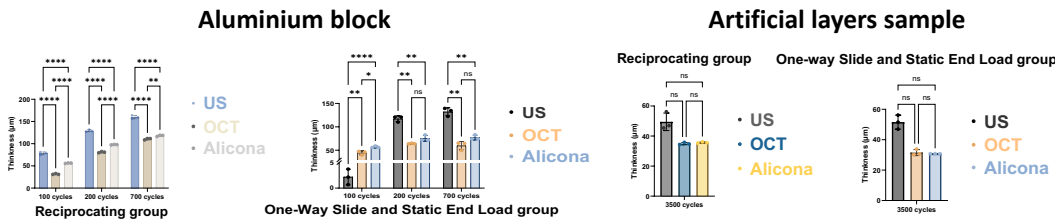


Fig. 2 Results of the depth and statistical analyses between each measurement technique.

In order to analyse actual tooth material and more realistic surface geometries, bovine and then extracted human teeth will be analysed in the future.

Wednesday, 2025-07-30		HG E7		
Invited Talks	9:00-9:45 9:45-10:30	Chair: Emanuel Tack Rosa Espinosa : Soft Tribology Lars Pastewka : How multi-scale roughness affects contact, friction and adhesion		
Wednesday, 2025-07-30		HG E33.5	HG F 26.3	
Coffee	10:30-11:30		10:30-11:30	
Sessions	Tribological Testing III	Chair: Gary Nicholas	Data Analysis and Modelling V	Chair: Julien Keraudy
Talk 1	11:30-11:50	Michael Pusterhofer : Static friction measurement of steels under dry and lubricated conditions using an Optimol SRV tribometer	11:30-11:50	Michele Barsanti : Statistical analysis of tilting pad journal bearing dynamic coefficients: influence of measurement uncertainty
Talk 2	11:50-12:10	Jakob Gussmagg : Model testing of piston ring – cylinder liner contacts in mid stroke regime - An addition to linear tribometers	11:50-12:10	Toshiki Watanabe : Two Mechanical Scenarios of Stick-to-Slip Transitions with Slow Slip
Talk 3	12:10-12:30	Roland Sampl : Model-Based Testing and Validation of Brake Pad Friction Behavior Using a Dynamometer	12:10-12:30	Alessandro Sicilia : Investigating mixed lubricated tribo-systems modelled with fractal rough surfaces
Talk 4	12:30-12:50	Oleksii Nosko : A laboratory setup to generate and collect brake wear particulate matter for chemical and toxicological characterisation	12:30-12:50	Amirmasoud Kiakojouri : A Generalized CNN-Based Model for Robust Bearing Fault Diagnosis Using Numerically Simulated Data for Training
Lunch	12:50-14:00		12:50-14:00	
Sessions	Tribological Testing IV	Chair: TBA	Data Analysis and Modelling VI	Chair: Tunç Ciftci
Talk 5	14:00-14:20	Matthias Breitegger : Experimental evaluation of a gas engine Ring-on-Liner contact under hydrogen atmosphere	14:00-14:20	Hitoshi Washizu : Bottom-up Modeling for Understanding of Tribology
Talk 6	14:20-14:40	Vikas Kumar Singh : Design and Development of a High-Precision Force-Controlled Pendulum Tribometer	14:20-14:40	Anuj Khare : Modelling transient wear characteristics in plain bearings
Coffee	14:40-15:40		14:40-15:40	
Wednesday, 2025-07-30		HG E7		
Final Words	15:40-16:10	Farewell, and next meeting		

Static friction measurement of steels under dry and lubricated conditions using an Optimol SRV tribometer

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For the dimensioning of press fits and screw connections, knowledge around the static friction coefficient between two surfaces is essential. Variation of the surface and the state of lubrication can change this parameter. The research in this paper presents a novel screening method for the static coefficient of friction, using an SRV tribometer from Optimol Instruments Prüftechnik GmbH. It is shown that the static coefficient of friction can be screened with high accuracy on a model test base.

The materials which were investigated, were two types of steels (stainless steel 1.4313 and heat-treatable steel 1.6511), combined in different ways, in dry or lubricated (wet) condition and also in nitrided condition.

The tests were carried out using the pin-on-plate method at 20Hz and 120MPa contact pressure. The novelty of the test procedure is the linear increase of the stroke, starting from almost zero. This means that there is no relative movement at the start of the test. As the actuator stroke increases, so do the shear forces due to elastic deformation of the components. These shear forces are perfectly measurable with the SRV's piezo force transducer. Finally, the shear force exceeds the static friction and sliding occurs.

Figure 1 shows a summary of the measured static friction coefficients, demonstrating that the method is perfectly capable of discriminating between different combinations in a reproducible manner.

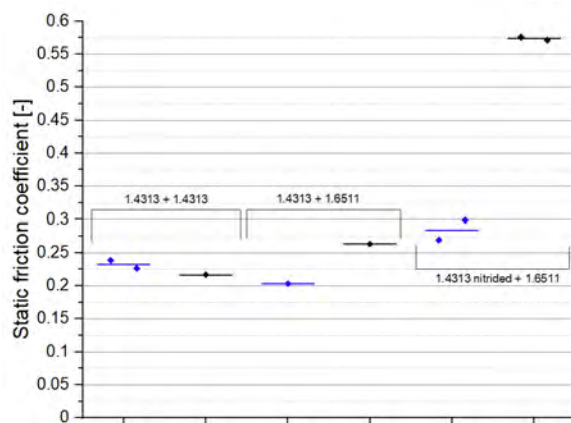


Fig. 1 Overview of results

Model testing of piston ring – cylinder liner contacts in mid stroke regime - An addition to linear tribometers

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Despite the declining prevalence of internal combustion engines (ICE) in numerous domains, suitable alternatives remain elusive in the field of HDD engines, large bore ship engines and power generators. In these areas, alternative fuels based on hydrogen and the use of very low viscosity oils are promising candidates for consideration. The mechanism of ICE results in distinct parameters over the entire stroke in the piston ring – cylinder liner contact, with the combination of low velocity and high pressure at the top dead centre being a particular focus of investigation. Conversely, the lower contact pressure but higher relative speed in the mid-section is less frequently the subject of investigation. This particular section is the focus of this study. A methodology for analyzing ring-on-liner contact under a constant parameter set, rather than oscillation, was developed in a rotational approach.

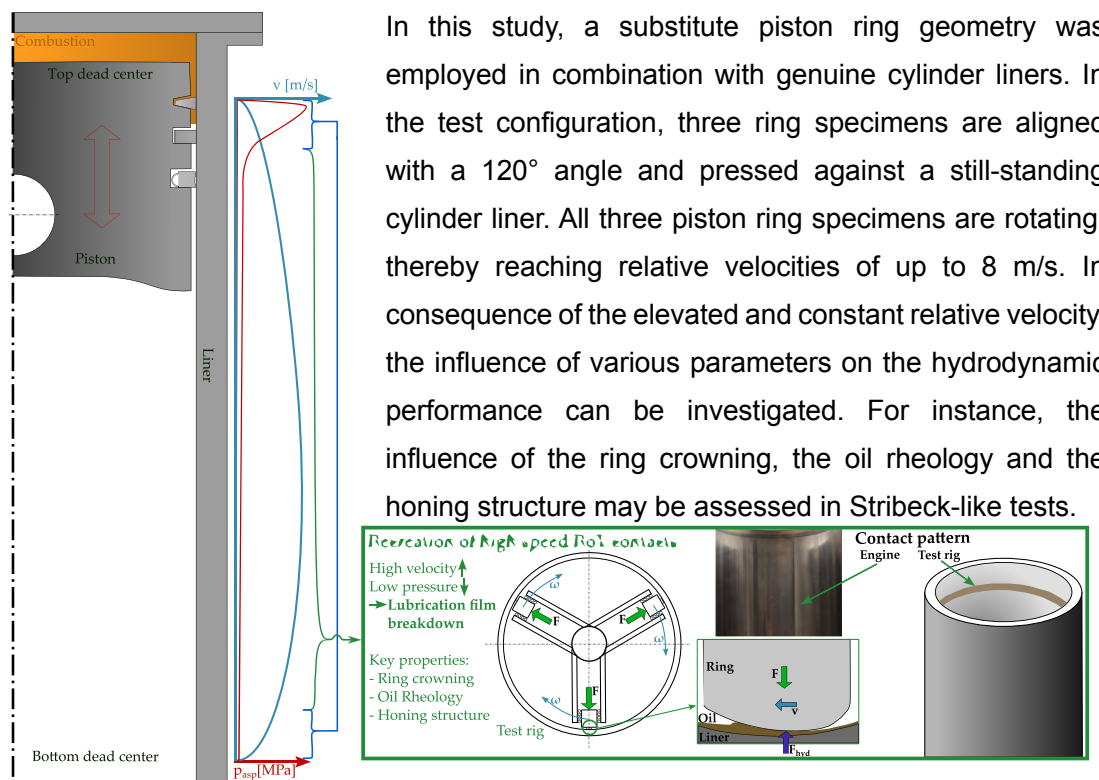


Fig. 1: Test configuration

Model-Based Testing and Validation of Brake Pad Friction Behavior Using a Dynamometer

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Automotive manufacturers must comply with increasingly stringent regulations regarding vehicle emissions. To meet the European Union's goal of zero emissions by 2050 [1], new material combinations for brakes and innovative braking systems must be developed or identified.

The effectiveness of brake materials is typically evaluated using an inertia dynamometer test method, such as SAE J2522 [2]. The purpose of this study is to compare the frictional behavior between tests conducted on an inertia dynamometer and those conducted on a pin-on-disc test rig, and to outline the parameters for both test setups. The experiments were conducted using the test setup shown in Fig. 1, where three pins rotate on a disc. The pins are made of a semi-metallic pad material, while the disc is made of nodular cast iron. The relative speed and contact pressure are set according to part of the SAE J2522 [2] test procedure, and the contact temperature is measured 0.5 mm from the contact surface.

Finally, friction data from brake test methods are compared and the potential use of the pin-on-disc test rig for brake pad testing is critically discussed.

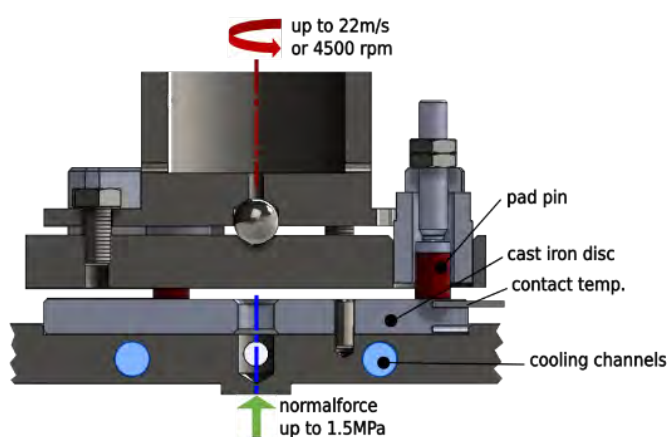


Fig. 1 Schematic Pin-on-Disc Setup

References

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- [2] SAE J2522, Inertia Dynamometer Disc and Drum Brake Effectiveness Test Procedure

A laboratory setup to generate and collect brake wear particulate matter for chemical and toxicological characterisation

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Particulate matter (PM) emitted from the brakes of cars and other means of transport is known to be one of the main anthropogenic sources of pollution in urban areas. Accurate characterisation of the morphological, chemical and toxicological properties of brake wear PM is crucial for evaluating its impact on the environment and health.

Based on a pin-on-disc tribometer, a laboratory setup was developed for the generation, classification by size and collection of wear PM. The setup ensures the elimination of external particle sources by enclosing the friction pair with an aerodynamic chamber and filtering the inlet airflow; the reproduction of friction conditions characteristic of light braking in terms of average sliding speed, contact pressure and temperature; the classification and collection of wear PM in size fractions of 2.5 to 10 μm ($\text{PM}_{2.5-10}$) and 1 to 2.5 μm ($\text{PM}_{1-2.5}$) by directing the outlet airflow into a cascade impactor; an improved efficiency of particle sampling by optimising the shape of the aerodynamic chamber and the position of the sampling point.

The setup was used to facilitate the chemical and toxicological analysis of wear PM emitted from car brakes. The pin sample imitated the brake pad, which was made of a low-metallic (LM) or non-asbestos organic (NAO) material, while the disc sample imitated the brake disc made of grey cast iron. The friction conditions corresponded to the braking of a car from an initial speed of 36 km/h to zero with a contact pressure of 0.5 MPa and a contact temperature below 100 °C. The setup enabled a PM collection rate of 3.6 mg $\text{PM}_{2.5-10}$ and 1.2 mg $\text{PM}_{1-2.5}$ for LM and 2.5 mg $\text{PM}_{2.5-10}$ and 0.7 mg $\text{PM}_{1-2.5}$ for NAO per hour.

This work was supported by Gdansk University of Technology through the Neptunium Enhancing Baltic Region Research Cooperation — 'Excellence Initiative — Research University' programme under grant code 3/1/2024/IDUB/II.2b/Np and EPSRC with funding

Experimental evaluation of a gas engine Ring-on-Liner contact under hydrogen atmosphere

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Gas piston engines play a crucial role in the transition to more sustainable energy sources. Optimising the tribological properties of piston engines leads to reduced fuel consumption. The majority of friction occurs in the piston group, particularly in the ring-on-liner contact. The use of hydrogen instead of natural gas could affect the tribology in the ring-on-liner contact. These effects include processes such as hydrogen embrittlement, hydrogen absorption by the oil and tribological reactions with the hydrogen during testing [1,2].

The basic principle of the linear tribometer used in this study is shown in Figure 1. A local gas atmosphere is applied directly to the contact between the ring and liner samples by spraying hydrogen through the sample holders. The contact temperature, contact potential, friction coefficient and acoustic emissions are measured to accurately analyse the tribological behaviour.

The newly developed localised hydrogen atmosphere test method has made it possible to evaluate the effect of hydrogen on the ring-on-liner contact without the need for a sealed hydrogen test chamber. Scuffing limit and friction are evaluated for conventional air and hydrogen atmospheres.

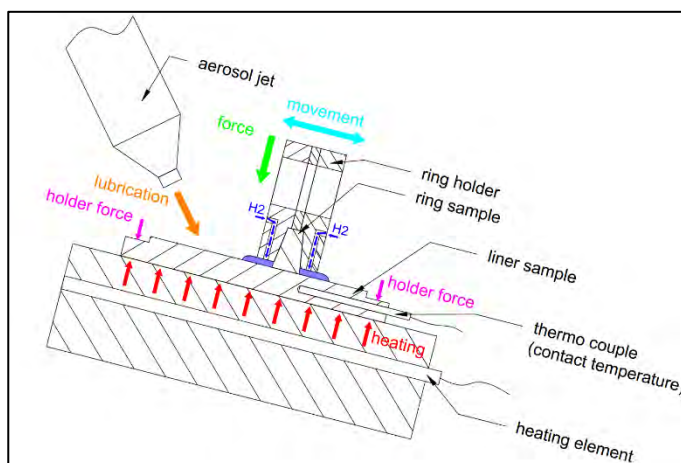


Figure 1 basic test principle

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Design and Development of a High-Precision Force-Controlled Pendulum Tribometer

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Tribometry measures friction and wear, which requires accuracy and precision in measurement. A critical aspect in evaluation is identifying the nature of tribo-contact motion—whether force-controlled or displacement-controlled. Tribo-contacts operating in the “Boundary Lubrication (BL)” regime typically exhibit force-controlled motion, requiring systems that replicate such conditions. Accurate measurements are often compromised by external factors such as system damping, inertia, and structural stiffness. These factors alter contact conditions, affect force transmission, and introduce errors in measurements. The use of motors in conventional tribometers further affects the Noise, Vibration, and Harshness (NVH) measurements, which are crucial for the tribo-contact analysis. To address these challenges, a Force-Controlled Pendulum Tribometer (FCPeT) has been developed. Unlike conventional tribometers, FCPeT avoids contact-type sensors to minimize compliance in the system and maintain force-controlled motion in the BL regime. FCPeT design uses a non-contact optical encoder to measure the angular position of the pendulum over time. The decay in oscillation amplitude shows a direct correlation with the friction in the system. An accelerometer and a microphone are in place to capture the friction-induced noise and vibration. FCPeT also features a temperature-controlled heater for high-temperature testing. FCPeT also enables conducting experiments at different “Slide to Roll Ratio (SRR)” at tribo-contact. After the experiments conducted at different SRRs, the tribo-contacts are evaluated using the pendulum configuration. The use of frictionless air bearings in FCPeT reduces machine-damping effects, which enhances precision in measurement. Previous studies using an earlier version of FCPeT (without SRRs) investigated the frictional behaviour of a base oil–stearic acid blend, a common organic friction modifier. The results showed a reduction in the coefficient of friction with increasing temperature [1]. This was attributed to the formation of a stable tribofilm at elevated temperatures. Building on these findings, the current work explores the influence of varying SRRs (0-200%) on tribofilm formation using

the present FCPeT (latest version). SRRs influence the film's stability, with low SRRs favouring uniform, stable layers, which directly affect the frictional and NVH performance [2]. Understanding these dynamics is key to optimizing lubricant performance.

Keywords: Tribometry, Friction, Force-Controlled, Pendulum Tribometer, Noise-Vibration and Harshness, Slide-to-Roll Ratio

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Statistical analysis of tilting pad journal bearing dynamic coefficients: influence of measurement uncertainty

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Dynamic coefficients of tilting pad journal bearings are typically determined by measuring forces and displacements in experimental tests. A methodology developed by the authors determines the dynamic coefficients by minimizing the sum of the squared residuals of displacements and forces, normalized with the uncertainty associated with the measurements themselves, that is the standard deviation of the population of measurements (Fig. 1). In this paper, we analyze the influence of the choice of such normalization. In previous works [1], standard deviations have been defined on the Cartesian coordinates in the complex plane of the displacement and force phasors. An alternative methodology defines the standard deviations on the polar coordinates of such phasors. We discuss the influence of the standard deviation values on the results of the minimization algorithm.

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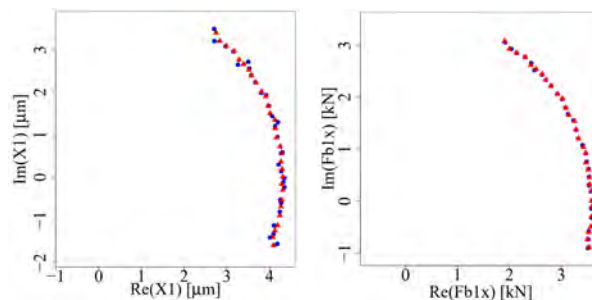


Fig. 1 An example of measurement of displacements and forces. Blue circles are measurements and red triangles are estimated values. Reproduced from [1].

Acknowledgments

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Two Mechanical Scenarios of Stick-to-Slip Transitions with Slow Slip

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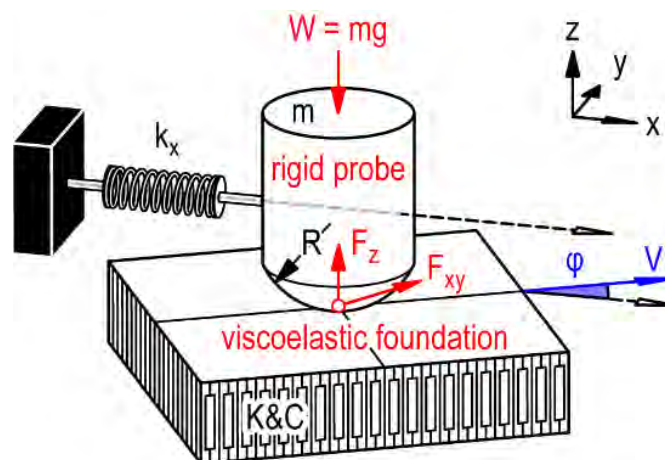
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The stick-to-slip transition is a fundamental tribological phenomenon from atomic to geological scales. A classical view explains that the sliding exhibits two states: stick and slip states generated by static and kinetic friction, respectively. However, several experiments have observed that extremely slow slips occur even in macroscopically stick states. Recent theoretical studies provide two scenarios to explain slow slip based on different models. One is due to the friction vector rotation caused by in-plane misalignment [1], and the other is due to the probe vertical lift caused by solid viscoelasticity [2]. This paper presents an idea to represent the two scenarios in a single model without explicit friction laws. Figure 1 shows the model: A rigid probe supported by a horizontal spring (k_x) is in contact with a viscoelastic foundation (K and C) moving at a constant speed (V) with a misalignment angle (φ) under a constant load ($W = mg$). Numerical simulation shows the two types of stick-to-slip transitions with slow slip. Theoretical analysis provides a clear picture of the relationship between the two scenarios.

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Investigating mixed lubricated tribo-systems modelled with fractal rough surfaces

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The aim of this work is to present the development of a numerical model able to simulate the Mixed Lubrication regime establishing between interacting surfaces. It is governed by the Elasto-Hydrodynamic Lubrication Reynolds equation and by the contact characteristic equation in different zones of the discretized domain, where the transition between lubricated and contact areas is managed by the introduction of a transition function leading to a global set of nonlinear equations: the set of equations is written in discretized form by the means of the Finite Difference Method and it is solved iteratively with the non-linear Jacobi algorithm.

The surfaces' deformability is taken into account and modelled with the Boundary Element Method supplied by the Boussinesq deflection kernel, while the surfaces' roughness is generated by the Random Mid-Point algorithm which models fractal surfaces depending on their Hurst exponent [1].

The code is applied to the tribo-system composed by a moving plane and a fixed rough surface (Fig.1): a sensitivity analysis is conducted and the tribological results are discussed.

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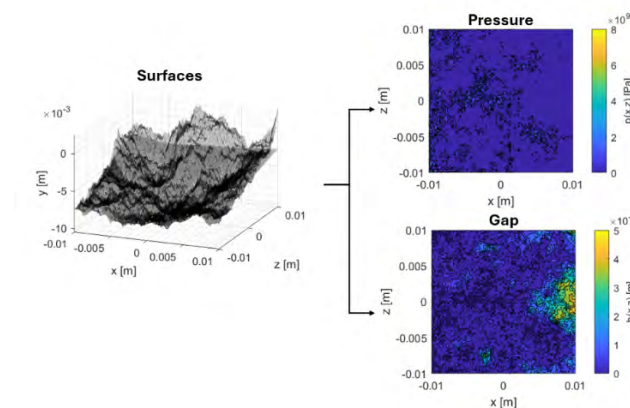


Fig. 1 Simulation of rough contacting surfaces

A Generalized CNN-Based Model for Robust Bearing Fault Diagnosis Using Numerically Simulated Data for Training

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Abstract

Rolling element bearings (REBs) are critical components in rotating machinery, with failures leading to significant operational and economic losses. Traditional fault detection methods, relying on classical signal processing techniques, suffer from limited generalizability due to variations in operating conditions and machine types. Additionally, deep learning (DL) models, particularly Convolutional Neural Networks (CNNs), have demonstrated superior fault classification accuracy; however, their deployment in industrial applications remains limited due to the scarcity of suitable data for model training and poor domain adaptation.

This study develops a CNN-based model trained exclusively using numerically simulated vibration data for a wide range of bearing designs. The model has demonstrated significantly high accuracy in diagnosing bearing faults created in laboratory experiments and real-world machines, indicating its generalizability. This approach eliminates the dependence of conventional modelling methods on extensive labelled experimental datasets.

To bridge the domain gap between simulated and real-world data, this study employs a hybrid signal processing method developed by the authors, integrating Cepstrum Pre-Whitening, high-pass filtering, and amplitude normalization, which enhances feature extraction and mitigates domain discrepancies. A 1D-CNN model, trained with a 34-feature input vector derived from numerically simulated vibration data based on bearing characteristic frequencies (BCFs) and noise parameters, achieved a training accuracy of 97.23% and a validation accuracy of 96.67% on simulated data. When applied to the Case Western Reserve University (CWRU) dataset without further training, a classification accuracy of 95.73% for diagnosable samples was achieved, significantly outperforming traditional machine learning and transfer learning approaches presented in the literature. Next, applying the model to data from a Safran jet engine ground test effectively identified both seeded and naturally occurring faults, demonstrating its robustness in diagnosing bearing faults in high-noise, non-stationary real-world machinery. The generalized CNN model established in this study makes a unique contribution to the future development of intelligent predictive maintenance strategies for industry.

Keywords: Bearing fault diagnosis; data scarcity; generalisability; simulated vibration data; convolutional neural network (CNN).

Bottom-up Modeling for Understanding of Tribology

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To realize Green Technology, friction and wear control is essential today. In this presentation, we report on a recent approach by using multiple computer simulations using world class super computers. Molecular dynamics (MD) has been useful for Tribology as a basic technique. Classical MD simulations, without chemical reaction, revealed the formation of friction modifier (oiliness additives) molecules can be analyzed [1]. The reactive force field simulation revealed the so called Tribo-chemical reaction [2]. Although molecular simulation is useful, Tribological phenomena is basically multi-scale. Large scale classical MD is used to understand the origin of surface slip on EHL oil film [3], but the analysis is quasi one-dimensional system, so that it is difficult to treat the other points such as surface roughness. The multiscale nature of Tribological phenomena should be treated in bottom-up material simulation method. To understand the Rheology of complex lubricants such as grease, aggregates of additives, or polymer solution, we model these fluids as “multiscale fluids”. The flow of base oil (solvent) is treated as continuum media calculated by Navier Stokes equation using Lattice Boltzmann method, and the solute by Langevin dynamics [4]. Using a new simulator, the effect of Brownian motion of a single solute polymer, for example, made complex flow in the whole system [5]. Practical modeling methods for chemical compounds are applied for viscosity index improver and biological system [6]. To understand the dynamics of solid surface in micron scale, we developed a simulator based on Smoothed Particle Hydrodynamics (SPH) [7]. The MD is used to tie the surface interaction with the SPH simulator [8]. Effect of heat transfer due to the friction on the surface is also treated, which cannot be discussed using MD [9]. The new SPH simulator treats plastic-elastic deformation of the surface [10] and research of the origin of flash temperature is ongoing.

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Poster Abstracts

Microtribology on Soft Substrates: Sliding and Rolling Friction

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Measuring tribological interactions at the microscale is essential for optimizing modern materials and devices. In our recent work, we extended lateral force microscopy (LFM) beyond its traditional role in measuring sliding friction to also quantify the rolling friction of free particles. [1] By attaching microprinted concave holders to the cantilever that confine fluorescently labeled particles, our method enables simultaneous monitoring of particle rotation and frictional response through combined LFM and fluorescence microscopy.

Building on these advancements, this project focuses on both sliding and rolling friction on compliant, adhesive substrates, i.e., nanoparticle-coated polydimethylsiloxane (PDMS). Starting with systematic measurements of sliding friction between a fixed colloidal probe and the (solvent-extracted) PDMS surface (**Fig. 1**), we visualize substrate deformation using confocal microscopy and tracking nanoparticle displacements. We then compare the measured friction forces with theoretical predictions derived from nanoparticle displacement data using point force solutions for linearly elastic half-spaces. Comparing sliding and rolling frictions while systematically varying parameters such as normal load, substrate stiffness, viscoelastic properties, and the colloidal probe's size, topography, and velocity could yield valuable insights relevant to biomedical applications, soft robotics, and wearable electronics.

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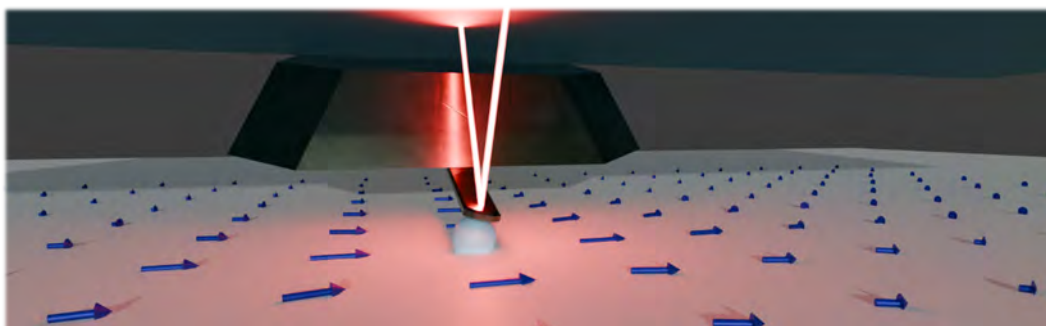


Fig. 1 Sliding experiment with a colloidal probe on PDMS: LFM detects cantilever torsion via shifts in red laser reflection (red beam). The blue arrows depict substrate displacement tracked by nanoparticles on the PDMS surface.

Past, present, and future of WS₂ fullerene-like nanoparticles in industrial tribological applications and fundamental research

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Reshef Tenne first discovered WS₂ fullerene-like (IF-WS₂) nanoparticles in the early 1990s as a new class of inorganic nanostructures with closed-cage morphology and exceptional mechanical resilience.¹ Since then, they have attracted attention for their remarkable tribological properties under extreme pressure and temperature.²

In recent years, IF-WS₂ has been successfully implemented in both industrial machining and automotive lubrication. In these technological operations, IF-WS₂ demonstrably reduces electricity consumption by 5–30 % and the use of oil in the emulsion fluids by 30–50 % while significantly extending tool lifespan. These benefits translate into lower energy use, extended equipment life, and reduced lubricant consumption. A key factor is the fact that these IF-WS₂-based products are not in the research phase – they are fully developed, proven in practice, and commercially available. Thanks to these advantages, technologies utilizing IF-WS₂ represent a promising direction of "green tribology."

In this contribution, WS₂ fullerene-like nanoparticles will be re-introduced from the historical perspective, long-term industrial experience, and current development in the synthesis of new WS₂ fullerene-like nanoparticulate morphologies.

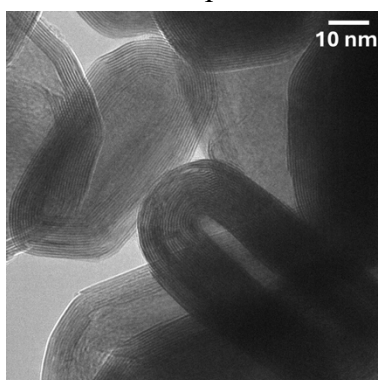


Figure 1. transmission electron microscopy analysis of WS₂ fullerene-like nanoparticles

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Vegetable oils in lubrication field

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Industrial lubricants, mainly from petrochemicals, pose a significant risk to the environment and human health. Vegetable oils in lubricant field is largely studied [1, 2]. Investigations on lubricant performances of vegetable oils have been carried out as lubricant base and as liquid additive in different mixtures. Graphite particles were used as solid additives [3]. The tribological properties of these lubricant formulations have been evaluated using a home-built ball-on-plane tribometer under ambient atmosphere. An influence of physicochemical - viscosity and fatty acid composition- properties on friction performances of these oils is demonstrated. Best friction reduction findings were obtained for vegetable oil as liquid additive highlighting the key role of triglycerides in influencing tribological performances.

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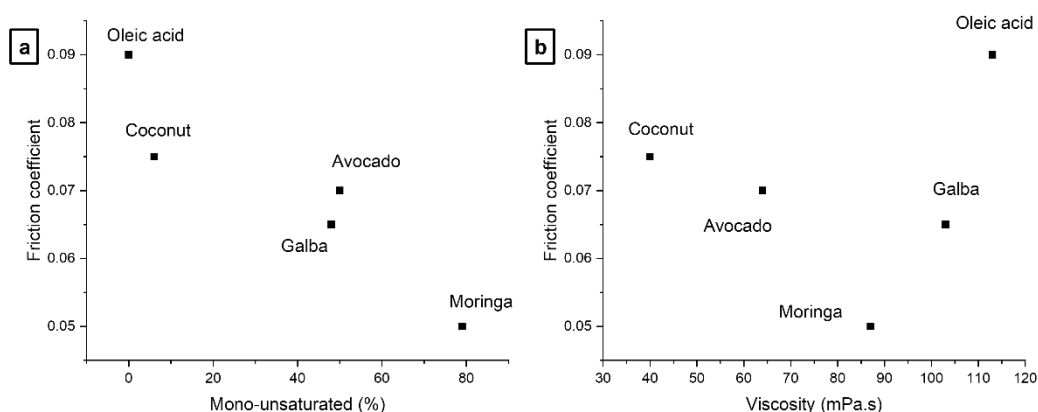


Fig. 1 The friction coefficient values of formulation with vegetable oil as liquid additive (2 w%) according to the percentage of mono-unsaturated molecules **(a)** and viscosity parameter **(b)**.

Contact Mechanics Analysis of Laser-Structured Surfaces: Linking Surface Deformation to Frictional Performance

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Understanding the relationship between surface deformation and frictional performance is crucial in tribology, particularly for frictionally engaged components such as flange connections or press fits. Laser-structured surfaces offer a promising solution by enhancing surface hardness locally and optimizing the interlocking of the generated microstructures and the counterbody surface, ultimately increasing transferable tangential forces. However, while experimental evidence supports friction enhancement through micro-interlocking [1], a comprehensive contact mechanics analysis of surface deformation behavior remains insufficiently explored.

In this study, three distinct laser-structured surface types are compared to a reference surface using an elasto-plastic contact mechanics approach. This method provides insights into how surface deformation influences frictional response. The limitations of the numerical model are discussed, and a clear correlation between surface deformation and frictional performance is established. Figure 1 illustrates the procedure briefly.

The results emphasize the potential of laser structuring in improving frictional engagement through tailored surface designs. Further developments and optimizations are proposed to refine the design process for friction-enhancing laser structures, offering valuable guidance for advanced tribological applications.

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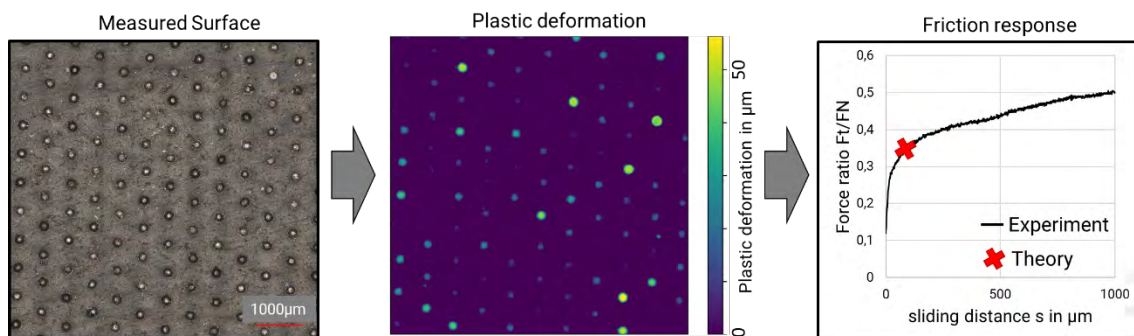


Figure 1: Flowchart of the procedure to identify effects of deformation on friction

Wear-Resistant Hydrogel Coatings with Antifouling Properties and High-Performance TENG Applications

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In pursuit of sustainable and multifunctional surface coatings for marine environments, we have developed a bio-based hydrogel coating using chitosan as the functional biopolymer. The coating exhibits excellent wear resistance, antifouling ability, and enhanced triboelectric output, making it a promising candidate for marine sensing and energy harvesting [1].

To improve mechanical robustness, an interpenetrating acrylic acid/chitosan crosslinking network [2] was introduced via covalent and physical entanglements, significantly enhancing the strength and integrity of the coating. The mechanical properties were quantitatively evaluated using both nanoindentation and scratch testing [3]. Nanoindentation measurements revealed a high elastic modulus and hardness, while progressive-load scratch tests confirmed strong resistance to surface damage and cohesive failure, even under high normal loads. These results demonstrate the capability to withstand continuous mechanical abrasion.

Antifouling performance was achieved through a synergistic design of zwitterionic components [4], which effectively reduced protein and microbial adhesion under both static and dynamic aqueous conditions.

In addition to its protective properties, the coating was integrated into a triboelectric nanogenerator (TENG) architecture [5]. The device exhibited high and stable electrical output, and more notably, a strong humidity-dependent enhancement in voltage. As ambient humidity increased, triboelectric output showed a consistent rise, enabling the TENG to serve as a potential self-powered humidity sensor.

This study provides a green, multifunctional material platform that integrates mechanical durability, surface antifouling, and humidity-responsive energy harvesting. It offers a promising pathway toward intelligent and sustainable marine monitoring systems.

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How is Fluid Film Established in a Sliding or Rolling Contact during Start-Up and Vanished during Stop Down?

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Based on the expanded Reynolds equations [1], Eqs. (1) and (2) shown below, the variations of fluid film thickness of a slider and a ball on a glass disk, the speed of which was increased or decreased fast with a servo-motor, have been analyzed numerically. It is shown that during the take-off and landing processes of the slider and the rolling ball, the dynamic term, $M(x,y,t)$, changes with time quickly and plays an important role in the hydrodynamic and elastohydrodynamic lubrications.

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$$\frac{\partial}{\partial x} \left(\frac{h^3(x,y,t)}{12\mu} \frac{\partial p(x,y,t)}{\partial x} \right) + \frac{\partial}{\partial y} \left(\frac{h^3(x,y,t)}{12\mu} \frac{\partial p(x,y,t)}{\partial y} \right) = \frac{\partial}{\partial x} (U(t)h(x,y,t)) + \frac{\partial}{\partial y} (V(t)h(x,y,t)) + \frac{\partial h(x,y,t)}{\partial t} - M(x,y,t) \quad \text{Eq.(1)}$$

$$\frac{\partial^2}{\partial t \partial x} \left(\frac{h^3}{12\mu} \frac{\partial p}{\partial x} \right) + \frac{\partial^2}{\partial t \partial y} \left(\frac{h^3}{12\mu} \frac{\partial p}{\partial y} \right) = \frac{\partial^2(hU)}{\partial t \partial x} + \frac{\partial^2(hV)}{\partial t \partial y} + \frac{\partial^2 h}{\partial t^2} - \frac{dM}{dt}. \quad \text{Eq.(2)}$$

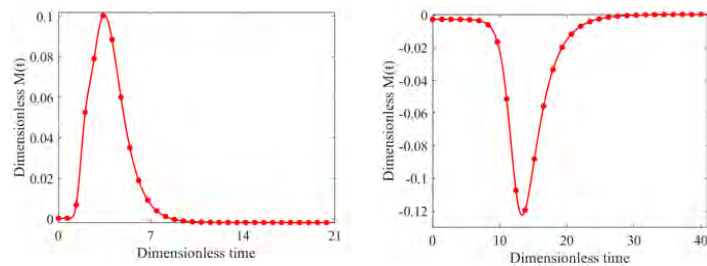


Fig. 1 Variations of the last term in Eqs.(1)&(2) during start-up (left) and stop down (right) of a slider on an accelerating rotating glass disk, inversely calculated according to the transient fluid film thickness measured with an optical interferometry method.

Additive manufacturing of numerically generated polymer rough surface topographies for triboelectric nanogenerators.

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An approach to rapidly produce high-quality polymer surface topographies from numerically generated surfaces for application in triboelectric nanogenerator (TENG) devices is presented. The approach uses an advanced surface generation tool to flexibly design surfaces with user-defined topography characteristics over a large range of surface roughness. Roughness instances with root mean square roughness 25, 50, and 100 μm are studied. 3D printing is used to create a master surface and polymer casting and injection molding are employed to enable rapid replication in various polymers. The cross-correlation ratio (CCR) and a mean difference approach were used to assess replication quality. Injection molding provides high throughput with high replication quality up to $\text{CCR} \approx 0.74$. While casting in low-viscosity polymer resins enables slightly improved high-quality replication (CCR up to ≈ 0.82) with reduced throughput. Key results include the ability of the 3D-printed surfaces to replicate tailored variations in surface topography (e.g., amplitude and frequency) and the importance of low viscosity resins in maximizing replication quality in polymer casting. Several interfacial and surface phenomena (both mechanical and biological) are sensitive to surface roughness. The main application for this surface fabrication approach has, so far, been the fabrication of surfaces for triboelectric nanogenerators (TENGs). The method has proven to be very useful in investigating the influence of different topographical characteristics on the electrical performance of TENGs.

Tribological Performance of SiC- and TiC-Reinforced AlSi7Mg0.6 Composites Processed by High-Speed Laser Cladding

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Metal matrix composites (MMCs) reinforced with ceramic particles are promising for tribological applications requiring wear resistance and weight reduction. AlSi₇Mg_{0.6} is widely used for its castability, mechanical properties, and corrosion resistance [1], but its tribological performance remains a challenge. To improve wear resistance, SiC and TiC reinforcements are introduced. While SiC offers hardness and wear resistance [2-3], it can lead to needle-like structures and inhomogeneities [3]. In contrast, TiC provides great interfacial bonding [4], potentially enhancing coating stability and wear resistance [5].

In this study, high-speed laser cladding was used to fabricate AlSi₇Mg_{0.6} composites reinforced with 20%, 30%, and 40% SiC or TiC on AlMg₃ substrate. The laser process influenced the microstructure and coating integrity by promoting partial dissolution of the carbides, especially SiC. The partial dissolution of the carbide reinforcements contributes to increased matrix hardness through dispersion strengthening but does not necessarily enhance wear resistance. Pin-on-disk tests were conducted to determine the optimal volume fraction of each carbide (SiC and TiC) that achieves the best balance between hardness and wear performance.

Microstructural analysis revealed that SiC-reinforced composites form needle-like phases and free Si due to carbide dissolution, which negatively affects wear resistance. In contrast, TiC showed minimal dissolution and formed more uniform coatings. For both reinforcements, wear resistance improved with increasing volume fraction up to 30 vol%. These results support the optimization of carbide-reinforced aluminum composites for wear-critical applications.

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Comparative Tribological study of Materials in Hydrogen ICE Seat-Valve Systems Using Pin-on-Disc Testing

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The durability of the seat-valve interface is critical for the reliable operation of hydrogen-based internal combustion engines (H2ICEs), where harsh operating conditions and fuel characteristics impose stringent demands on material performance. This study presents a comparative tribological evaluation of three different seat materials—comprising two Cobalt and molybdenum-type and a Copper and Berilium-type alloys—paired with a Stellite F valve material. Using pin-on-disc testing, the investigation simulates the sliding and contact conditions typical of the seat-valve interface in hydrogen ICE applications. The contact conditions have been evaluated by Finite Element Method analyses. Contact pressure and sliding distance have been estimated and used as reference for the experimental tests on the tribometer.

A Stellite F pin has been produced for the upper sample, and the seat component has been directly used as the counterface. Key performance indicators, such as wear rate and friction coefficient, were measured under controlled conditions (Fig.1) to assess the tribological performances of the seat materials.

The results reveal significant differences in wear behavior among the tested seat materials, with one Cobalt and molybdenum-type alloy demonstrating notably enhanced wear resistance and lower friction, thereby suggesting its potential for extended service life in valves of H2ICE.

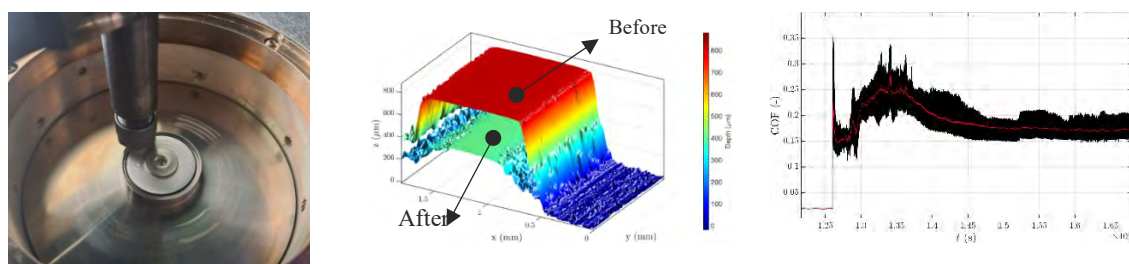


Fig.1 Left: Pin-on-disc Setup. center: 3D reconstruction of worn surface. Right: COF signal.

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Integrating Green Tribology into Product Design: A Planetary Boundaries Approach to Absolute Sustainability

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Green Tribology has evolved significantly over the past two decades, focusing on optimizing lubricants, coatings, and materials to enhance durability while minimizing frictional wear and environmental impact [1]. Traditional sustainability assessments in tribology, such as Life Cycle Assessment (LCA) or lifecycle tribology [2], rely on relative comparisons rather than defining absolute sustainability. To address this, the absolute sustainability framework [3], based on the planetary boundaries concept [4], provides a more precise approach. This study explores how absolute sustainability can be integrated into the product design phase, ensuring sustainability considerations are taken into account in early tribosystem development as pictured in Fig. 1. By aligning environmental impact assessments with functional and economic optimization, this approach transforms how sustainability is implemented in tribology, shifting the focus towards a system-wide perspective.

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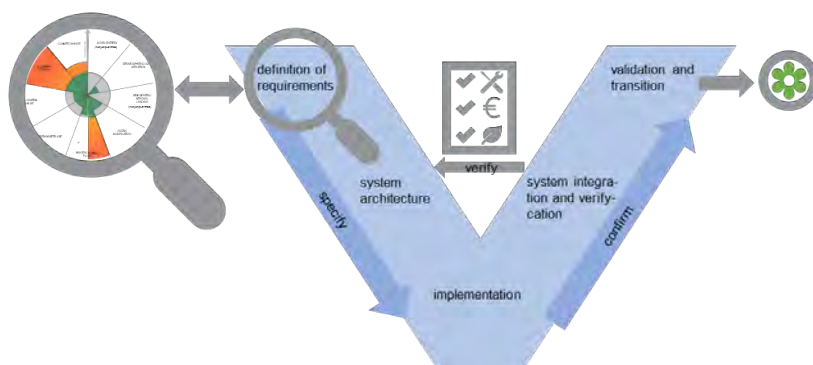


Fig. 1 Embedding absolute sustainability approach in design phase based on [4], [5]

Impact of tribology on energy dissipation at mechanical contacts: Thermodynamics

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Climate changes are affecting cities worldwide in ways including damage of infrastructure, disrupt economies, affect human lives, impact local ecosystems, and exacerbate urban vulnerabilities. IPCC Report on Climate Change and Cities is paved advances in urban climate science as well as climate and environmental adaptation, and mitigation. The governance must advance to support climate action in a potential world of 1.5°C degree temperature rise limitations. The transport sector alone is responsible for more than 7 Giga Tones of CO₂ loadings on environment for researching of energy sustainability. The hybrid electric technology used by automobile industries in India enhancing mechanical efficiency than conventional IC engines. The Net Zero Emissions (NZE) by 2050 Scenario of IEA primarily for reducing CO₂ emissions from the transport sector require political regulations and spending infrastructure to enable low-emission vehicle operations. The impact of friction, lubrication, and wear or "Tribology" is vast on society for designing and manufacturing of sustainable solution by reducing CO₂ emission primarily from transport sector at the forefront of United Nations Sustainable Development Goals. The science of friction, wear and lubrication on March 9, 2006 is the 40th anniversary of the "Tribology" and the lubrication engineering in 1966. The new technology of tribology is useful in economy of sustainable energy and bio-inspired materials of low surface energy in controlling friction.

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Vacuum Thermal Treatment for Achieving Superlubricity by Nanodiamond and Hexagonal Boron Nitride on H-DLC Film Surfaces in Dry Nitrogen

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Hydrogenated diamond-like carbon (H-DLC) films are limited by their poor thermal stability, which significantly affects the tribological applications and needs improvement. Accordingly, nanodiamond (ND) and hexagonal boron nitride (h-BN) are used to address this issue. When the H-DLC surface is deposited using ND+h-BN mixture with mass ratio of 1:1 and a concentration of 0.1 mg mL⁻¹ and vacuum-heated at 200 °C and 1×10^{-5} Pa, a superlow friction coefficient of 0.0015 can be obtained, with a reduction of 98.33% as compared to pure H-DLC. Correspondingly, the wear rates of wear scar and wear track decreased by 81.95% and 24.83%, respectively. High vacuum thermal treatment can purify the adsorbed species on the surfaces of ND and h-BN, and produce newly-exposed dangling bonds. Simultaneously, new bonds of C-N are formed between ND and h-BN, and the nanoparticles adhere together to form a polymer-like structure under friction. Furthermore, the ND can support h-BN and reduce its agglomeration. Under the action of tribochemical reaction, the layer spacing of hexagonal boron nitride is increased to obtain a better shear slip. The combination of these factors resulted in ultra-low friction. This study paved the way for developing functional anti-friction additives for durable and high-performance lubrication.

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Electronic energy dissipation in a sliding nanocontact

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Understanding energy dissipation at the nanoscale is critical for advancing nanotechnology and designing energy-efficient nanosystems[1]. In this study, we aim to investigate the mechanisms of electronic energy dissipation in a sliding nanocontact using molecular dynamics simulations in LAMMPS [2]. It is a well-known phenomenon that when two surfaces slide against each other, energy is dissipated resulting in friction. In the case of a contact involving metallic materials, the frictional energy is not solely dissipated as heat energy, but also through the channel involving the electronic degrees of freedom.

Here, we employ a semi-classical approach[3] to explore the electronic contribution to energy dissipation during a sliding contact between a Si nanotip and an Al substrate. The total friction force between the tip and substrate exhibits a stick-slip pattern. Increasing the spacing between the tip and the substrate decreases the total friction. We investigate the electronic contribution by means of velocity-velocity autocorrelation function.

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Exploring the role of friction on crystal rotation

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Friction is a well-known, yet little understood phenomenon in mechanical systems. It not only dissipates energy but in metals and alloys also alters surface and subsurface properties by modifying the microstructure. Under tribological loading, phenomena such as dislocation self-organization, grain refinement and oxidation can occur. The complete rotation of the entire subsurface parts of the materials was observed as an underlying mechanism that takes place prior to grain refinement. However, this apparently universal deformation mechanism in copper and copper alloys is far from sufficiently understood.

Using a copper single crystal, which was loaded with different frictional forces by changing the contact conditions, we investigated how the crystal rotates under tribological load. No friction was measured during indentation, while rolling and lubricated sliding produced low friction; the highest friction occurred for dry sliding. With increasing friction forces, the applied stress field resulted in a greater shear stress component, activating more slip systems.

Surface profilometry and electron microscopy reveals that the surface topography is surprisingly similar for all experiments showing similar depth, pile-ups and slip traces. However, cross-sectional micrographs show only minimal microstructural changes for low friction and more pronounced deformation for higher friction. Electron backscatter diffraction (EBSD) results indicate low crystal rotation for low friction and higher misorientation angles correlating with higher friction.

These findings suggest that the normal load is the driving factor for topographical changes, while the friction force is the key factor for the crystal rotation and associated microstructural changes.

Wear of Femoral Head Taper Connections of Total Hip Prostheses

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The success of total hip arthroplasty procedures depends on the performance and durability of different implant components and features, including the femoral head taper connection. Understanding the tribological aspects of this interface is important for improving patient outcomes. Despite recent progress, wear and micromotion at the taper connection remain issues which may lead to implant failure and revision surgeries [1], [2]. This study evaluates the wear performance of various implant materials under conditions mimicking in vivo environments to enhance prosthetic joint longevity [3]. The study involved load frame tests and hip joint simulator tests, two contemporary titanium alloy femoral stems designs, and both CoCr and zirconia toughened alumina (ZTA) femoral heads of 36 mm diameter against vitamin E stabilized, highly crosslinked polyethylene liners. Load frame tests applied dynamic loads, potentially causing micromotion and wear, while hip joint simulator tests mimicked walking conditions. An assembly force of 2.3 kN was systematically applied, and disassembly forces measured.

Stereomicroscope and SEM revealed that wear was more prominent in the inferior and distal parts of the CoCr head tapers, and these regions aligned with those of the trunnions that showed the most wear. Wear marks on CoCr heads were relatively mild, indicative of fretting due to micromotion. Material displacement occurred locally without dislodged debris. ZTA heads mainly showed titanium transfer by adhesive wear. ZTA femoral heads outperformed CoCr heads in terms of wear resistance and surface stability. 12/14 tapers showed more pronounced wear and surface modifications than Type 1 tapers. EDX analysis confirmed the absence of adhesion between CoCr and Ti alloy and increased oxygen percentage on worn regions. Overall, the wear marks were mild, and no serious damage was observed. The wear behaviour of the different taper connections appeared satisfactory.

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Dispersibility and stability of Stöber silica spherical particles in glycerol base fluid

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The work was focused on evaluation of compatibility and dispersibility of Stöber silica spherical particles with diameter ranging from 80 to 250 nm in glycerol base fluid and their stability against sedimentation.

Optimised Stöber technique based on tetraethyl orthosilicate (TEOS) hydrolysis and subsequent polycondensation of silica oligomers in alcoholic solutions in the presence of ammonia was used. The varied synthesis conditions in ethanol were as follows: 0.28 mol/L of TEOS, 0.55-2.00 mol/L of ammonia and 3.00-4.80 mol/L of water. The performed transmission electron microscopy (TEM) examination confirmed the uniform size of the synthesised silica spheres (Fig. 1).

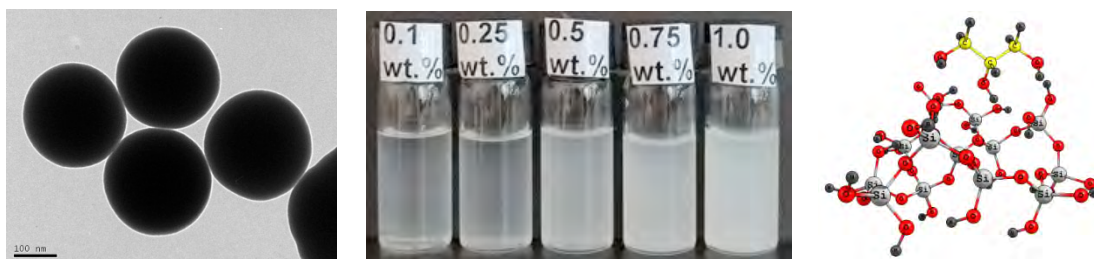


Fig. 1 TEM of Stöber silica particles of 230-250 nm diameter, their sedimentation stability in glycerol after 1 month storage, and simulation of glycerol – silica surface interaction

The dispersibility and stability against sedimentation of the synthesized silica particles of in glycerol was examined by evaluation via visual comparison of their precipitation behaviour. To prepare the dispersions of 0.1 - 1.0 wt. % concentration, silica particles were mixed with glycerol and then underwent treatment with ultrasound probe for 1 min. It appeared that all synthesised silica particles displayed stability being homogeneously dispersed in glycerol (Fig. 1). The origin of high dispersibility and stability against sedimentation of the synthesised Stöber silica particles was confirmed by DFT simulation (B3LYP functional with 6-31(d,p) basis set) of glycerol molecule interaction with silica surface ($\text{Si}_{13}\text{O}_{15}(\text{OH})_{22}$ cluster) whose Gibbs energy was found to be -24.9 kJ/mol at 298 K (Fig. 1).

Fretting Wear Behavior of Plasma-Sprayed CNT-Reinforced Wollastonite-Zirconia Composite Coatings

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This work explores the fretting wear behavior of plasma-sprayed wollastonite-zirconia (WaZr) composite coatings, with and without carbon nanotube (CNT) reinforcement, for bioimplant applications. Comparative analysis was conducted with conventional hydroxyapatite (HA) coatings deposited on titanium substrates. Microstructural observations revealed that the addition of CNT results in a denser, more uniformly bonded WaZr-CNT coating by enhancing splat bridging and reducing porosity. Mechanical testing indicated higher hardness and lower elastic modulus for WaZr-CNT compared to unreinforced WaZr coatings. Under fretting wear testing at a 200 μm displacement amplitude, the WaZr-CNT coating showed a remarkable reduction in energy dissipation, 83% lower than HA and 75% lower than WaZr coatings, reflecting a significant improvement in fretting resistance. Wear analysis further demonstrated that, while HA and WaZr coatings suffered splat fracture and generated a substantial amount of wear debris, the WaZr-CNT coating exhibited minimal debris formation and preserved splat boundaries. This study introduces CNT-reinforced WaZr coatings as a promising solution for enhancing fretting wear resistance in cyclic sliding contacts, relative to unreinforced WaZr and traditional HA coatings.

A Probabilistic Framework for Gear Wear Monitoring Using Imaging-Based Classification and Regression

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Real-time monitoring of gear wear is critical for ensuring mechanical reliability and minimizing downtime in power transmission systems. This study investigates the characterization of wear debris as an indicator of gear health under dynamic operating conditions and varying lubricant states. Traditional monitoring techniques often overlook the uncertainties associated with wear evolution, particularly under lubricant degradation. This work presents a data-driven framework that combines wear debris imaging, artificial neural networks (ANN), and Gaussian process regression (GPR) for wear classification and trend forecasting with uncertainty quantification. Experiments using fresh and chemically degraded lubricants under controlled gearbox conditions revealed distinct wear behaviours. Fresh oil produced early large-particle formation followed by stabilization, while degraded oil caused delayed but accelerated wear due to corrosion. Online monitoring via metallic debris sensors and offline microscopic analysis enabled wear mode classification. Morphological features of debris images were used in ANN models to classify wear severity with confidence scores, while GPR predicted wear progression with uncertainty bounds, accounting for operational variability. This integrated approach enhances the robustness of condition monitoring and supports probabilistic decision-making for maintenance planning. The study highlights the potential of combining real-time sensing and machine learning with uncertainty modeling to improve gear life estimation and lubricant formulation strategies. The proposed methodology offers a scalable solution for intelligent diagnostics in tribological systems.

Keywords: Lubricant Condition Monitoring, Machine Learning, Digital Image Processing, GPR, Wear Debris.