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Book of Abstracts

Contents

Coatings and surface protection / 1

Structural, mechanical and corrosion resistance of Phosphorus-doped TiAlN thin film

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Doped TiAlN thin films are gaining unprecedented attention in recent times due to their functionality and tuneable properties to meet specific demands. The present article focuses on the influence of phosphorus-doped TiAlN thin films deposited using high-power impulse magnetron sputtering. Thin films of different elemental compositions of Ti, Al, and P were sputtered on AISI 5206 steel. The thin film cross-sectional morphology and architecture revealed dense and columnar structures. It was indicated that the (111) diffraction peaks in the XRD pattern shifted to higher angles, while the transverse optics (TO)/longitudinal optics (LO) frequency in the optic phonons region of Raman spectra shifted to the right with the modulation wavelength as the Al and P compositions increase. The elementary composition influences the mechanical properties with the maximum hardness of 28 GPa, and adhesion strength of 15 N attained in thin film with the highest Al and P content. The corrosion rate in all the thin films was reduced by at least two orders of magnitude compared with the uncoated samples. The addition of P increases the corrosion resistance of TiAl(P)N thin films.

Tribocorrosion science: new challenges and opportunities / 2

Influence of diffused hydrogen on the surface response of 316L stainless steel under cavitation-induced loading

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It has been established that hydrogen diffusion can significantly influence the mechanical response of metallic materials under various loading conditions. This phenomenon is particularly evident in reducing the ability for plastic deformation. The formation and collapse of bubbles inside a fluid, i.e., cavitation near a solid surface generates one of the most complex loading scenarios. The characteristics of localized, high-velocity, and cyclic loading inherent to this process may lead to material removal from the surface, a phenomenon known as cavitation erosion. The mechanical properties of the metal surface, affected by hydrogen, may alter the resistance against erosion wear under cyclic loading conditions during cavitation. In this research, 316L stainless steel samples were electrochemically charged in 0.05 M H2SO4 solution to reveal the effect of diffused hydrogen on mechanical behavior as determined through tensile testing. The cavitation erosion experiments were conducted on hydrogen-charged and uncharged samples in an ultrasonic cavitation test rig. The findings showed that hydrogen charging in H2SO4 resulted in a significant reduction in cavitation erosion damage of approximately 80% after 5h testing compared to the uncharged sample. After 2 hours of cavitation exposure, notable plastic deformation was observed on the eroded surfaces of the uncharged specimens, particularly manifested in the form of raised grain boundaries and slip bands, whereas the surfaces of the hydrogen-charged specimens predominantly retained their integrity. This was attributed to the increased resistance against plastic deformation after hydrogen charging probably due to the dislocation slip impediment by diffused hydrogen atoms.

Electrical and energy systems / 3

PLENARY TALK : Lubricants in electromobility - tribological requirements & challenges

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The rapid growth of electric mobility introduces unique challenges for lubricants, distinct from those in internal combustion engines. Key requirements include electrical compatibility to prevent short circuits, superior thermal managementto handle heat generated by batteries and motors, and material compatibility with plastics and seals. Lubricants must also address noise, vibration, and harshness (NVH) concerns due to quieter powertrains, while offering durability under extreme operating-conditions such as high speeds and temperatures. Extended oxidation resistance and low-viscosity formulations are essential to enhance efficiency and range. Additionally, water resistance and environmental sustainability are becoming increasingly important.Meeting these demands requires innovative lubricant technologies tailored for the evolving needs of electric vehicle systems.

Tribocorrosion science: new challenges and opportunities / 4

PLENARY TALK : Bearings in Hydrogen Environments - An Industrial Perspective

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Bearings are versatile machine components –they are found in a wide variety of environments, some of which contain high amounts of hydrogen. With the transition to a greener economy, it is time to revisit applications where hydrogen is a critical constituentin the environment. One product segment of particular interest is pumps and compressors, which have to be designed to operate to pressures of 1000 bar and at temperatures that can reach 200 °C, sometimes even higher. The design loads are also normally quitehigh: 3 GPa for a point contact and 1.5 GPa for line contacts. These combinations pose particular challenges on the steel and its microstructure. Given hardness levels above 60 HRC, the steel is already brittle to begin with. Additional hydrogen in the material,even at low ppm-levels, may prove critical to bearing performance.

In this presentation, common failure types in different environments will be discussed, including sub surface fatigue. Experience from applications will be shown together with current material challenges for bearings in hydrogen containing environments.

Bio-tribocorrosion and related phenomena / 5

Comprehensive Pre-Clinical Evaluation of Spinal Implants: Corrosion and Wear under Physiological and Inflammatory Simulations

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Spinal implants, especially modular systems like bilateral instrumentation constructs, are susceptible to fretting corrosion due to micro-motion at interfaces. This study presents a novel combined biomechanical and electrochemical testing setup for pre-clinical assessment, enabling evaluation under sequential and physiological load conditions. The investigation included bilateral spinal constructs comprising Ti6Al4V pedicle screws and CoCrMo rods, tested in phosphate-buffered saline (PBS) and PBS supplemented with 30 mM hydrogen peroxide (H2O2) to simulate inflammatory conditions.

The experimental protocol involved uniaxial loading, flexion/extension, lateral bending, and axial rotation, applying over 250,000 cycles. Electrochemical data, such as open circuit potential (OCP) and corrosion currents, were recorded, alongside material degradation analysis through gravimetry, microscopy, and inductively coupled plasma mass spectrometry (ICP-MS). Physiological testing incorporated combined motion profiles, offering a closer simulation of clinical conditions.

Results showed pronounced corrosion and wear under H2O2 conditions, with a fourfold increase in ion release and higher fretting currents. Combined motion testing revealed significantly higher material loss compared to sequential testing, with Ti6Al4V pedicle screws exhibiting up to a 14-fold mass loss increase. Surface analysis confirmed oxide layer damage, third-body accumulation, and material transfer between components. ICP-MS revealed elevated Co, Cr, and Ti ion concentrations, highlighting the aggressive nature of the inflammatory environment.

This study underscores the importance of incorporating inflammatory simulations and complex motion profiles in pre-clinical testing to enhance implant design and ensure patient safety. The novel methodology establishes a benchmark for evaluating wear and corrosion mechanisms in spinal instrumentation systems.

Tribocorrosion science: new challenges and opportunities / 6

Development and Validation of an Integrated Real-Time Tribocorrosion Assessment Framework

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The development of robust preclinical evaluation techniques for orthopaedic implants is critical in light of recent high-profile implant failures and the increasing regulatory demands of EU MDR and FDA guidelines. This study introduces a novel framework integrating real-time wear-corrosion and wear debris analysis techniques for the comprehensive assessment of implant degradation mechanisms.

A bespoke tribometer, incorporating Acoustic Emission (AE) sensors, near-interface displacement sensors, and in situ electrochemical measurement systems, was developed to simulate and monitor wear-corrosion mechanisms under physiological and adverse conditions. Real-time data collection included coefficient of friction (CoF), electrochemical current, AE energy, and wear debris analysis using microfluidics and Raman spectroscopy.

Preliminary experiments using low-carbon CoCrMo samples paired with Al2O3 counter-surfaces under controlled loads and sliding conditions revealed critical insights into tribocorrosion behaviour. Real-time AE data demonstrated strong correlations with volumetric wear and corrosion currents, allowing predictive modelling of degradation. Post-test surface analyses confirmed the synergistic effects of wear and corrosion, identifying dominant wear mechanisms such as abrasive grooving and tribofilm formation. Wear debris characterisation using Nanoparticle Tracking Analysis (NTA) provided critical data on particle size, distribution, and chemical composition.

This framework establishes a pathway for real-time monitoring of tribocorrosion processes, offering enhanced precision in evaluating material degradation. The findings support the hypothesis that integrating multi-sensor approaches can significantly improve the reliability and efficiency of preclinical testing for implant systems. Future work will expand the methodology to clinically representative scenarios using advanced simulators and prolonged testing protocols. This innovation represents a step-change in orthopaedic implant evaluation, aiming to reduce testing timescales and improve patient outcomes.

Materials and mechanisms / 7

Understanding tribocorrosion of active steels: a combined experimental and numerical approach

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Tribocorrosion research have greatly advanced our understanding of the interplay between wear and corrosion in different materials. While considerable progress has been made in elucidating the tribocorrosion responses of passive alloys such as stainless steels, the combined effects of corrosion and mechanical wear in active steels remain less explored.
In this work, the tribo-electrochemical behaviour of active steel DC01 has been investigated under tribocorrosion conditions in a 1M NaCl solution. Potentiodynamic and potentiostatic measurements, the Scanning Vibrating Electrode Technique (SVET), and detailed surface analyses using (FE-SEM and EDX) are employed to examine how interfacial oxygen, evolving surface roughness, and oxide-layer formation governs corrosion mechanisms. To further elucidate tribocorrosion behaviour, we conducted a series of tribological tests under corrosive conditions, differentiating the contributions of corrosion, electrode agitation, and mechanical wear. Building on these experimental insights, a tribocorrosion model is proposed that integrates a Phase Field framework, capturing the time-dependent metal-electrolyte interface, ion and oxygen distribution, with a contact, friction, lubrication, and wear model to simulate surface evolution. This integrated model provides deeper insight into how time-dependent electrochemical processes, oxygen availability, and tribomechanical contact govern the tribocorrosion performance of active steels.
Our findings show that tribocorrosion in DC01 is largely controlled by corrosion and the formation of a porous oxide layer. Notably, the mechanical wear primarily enhances the electrochemical response through a stirring effect, increasing dissolved oxygen at the interface and thereby influencing the overall tribocorrosion performance.

Materials and mechanisms / 8

Effect of composition and heat treatment strategy on corrosion and tribo-corrosion properties of high-speed steels

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The aim of our study was to evaluate the tribo-corrosion properties of different grades of high-speed steels subjected to different heat treatment strategies. Conventionally heat-treated steel grades were compared to un-conventionally treated comprising cryogenic treatment cycle in order to investigate the effect of chemical composition, microstructure and hardness of the material on tribocorrosion properties.
Microstructural properties were first determined through observation of the metallographically prepared steels using scanning electron microscopy. The hardness of steels was also measured. These studies were complemented by an investigation into corrosion via different electrochemical techniques: corrosion potential measurement and linear polarization measurement of steels in a sodium tetraborate buffer at pH 10. Tribocorrosion properties were studied in the same solution using reciprocating sliding in order to study the effect of microstructure, hardness and passive properties of different grades of high-speed steels.
This study investigates the impact of heat treatment strategy on microstructure and the resulting hardness of the steels, which varies with their chemical composition. Corrosion studies will explore methods to differentiate the corrosion properties of the steels following different heat treatment strategies and cycles. Additionally, tribocorrosion properties will be evaluated using various approaches to assess steel grades subjected to different heat treatment strategies, with varying carbon and chromium content which further affect passive properties. The aim is to identify an optimal test procedure that reliably identifies the key properties of steels studying tribocorrosion performance.

Tribocorrosion science: new challenges and opportunities / 9

Tribological characterization of high-performance polymer composite (HPPC) for compressor piston rings in hydrogen environment

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The global transition to renewable energy depends heavily on the utilization of hydrogen. Since hydrogen is of low density and gaseous, it must be compressed to pressures exceeding 500 bar to achieve practical energy density for efficient storage and transport. This demands compressors with long service life and high efficiency. To achieve this, reciprocating piston compressors rely on advanced fiber-reinforced polymer based sealing solutions for piston and rod packing rings. However, future regulatory restrictions on fluorinated polymers, widely used in tribological applications, pose significant challenges to this industry.
The focus of this study was the development of application oriented and model tribometer tests in different gas atmospheres for efficient characterization and screening of high-performance polymer composites (HPPC), tailored for compressor piston rings and other components in high-pressure hydrogen applications.

Tribocorrosion science: new challenges and opportunities / 10

PTFE and MoS2 as two competing solid lubricants for dry-running hydrogen compressors

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In modern societies, efficient and resilient production and processing of energy are key requirements for a circular economy, which safes resources and reduces pollution of our natural environment. Therefore, the international climate agreement (Paris 2015) has set the maximum allowed global warming from the beginning of the industrial age below 2°, which needs a drastic reduction of greenhouse gas emissions, including CO2 until 2030 and net neutrality until 2050. To achieve a CO2 neutral energy supply, fossil energy carriers like oil and natural gas have to be completely replaced by green hydrogen produced by renewable energy sources. The existing power grid and energy storage technology is subject to subsequent adaptation from CH4 operation to H2 by combined repurposing of existing and development of new technology. Therefore, advanced sealing materials have to be developed to handle the volatile H2 gas at higher pressures to preserve comparable energy densities, like CH4 and in dry operation to avoid unwanted contamination of the gas by oil lubricants.

The current work describes a comparative study of carbon fiber-reinforced PPS composites with different types of solid lubricants, developed as high-pressure sealing materials in dry-running piston compressors. Advanced characterization by electron microscopy and synchrotron tomography, supporting tribological testing, shows deformation behavior under simulated pressure forces and tribofilm formation and its mechanisms in predicted operation modes. PTFE and MoS2 could be directly compared on a micromechanical level, and main differences in their self-lubricating mechanisms could be derived. The results show the advantages of the well-known PTFE lubricated tribo-systems compared to new observations on the MoS2 lubricant. Advantages and limitations of both systems show applicability of sealing materials for dry-running hydrogen compression and give insights in MoS2 performance with respect to PTFE substitution, necessary to fit potential requirements of future PFAS regulations.

Bio-tribocorrosion and related phenomena / 11

Hemiarthroplasty and Cobalt Chromium Ion Release into Cartilage

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INTRODUCTION: Cobalt-Chromium (CoCr) alloy is a common material for hemiarthroplasty. In this scenario only one side of the diseased joint is replaced, thus that the opposing cartilage articulates against the prosthetic device. Hemiarthroplasty is a promising treatment option for mild joint degeneration, offering the benefits of bone preservation and reduced operative time. However, in vitro work has shown that cell death at the articulating surface is accelerated when articulating against CoCr as compared to non-metallic replacement materials, despite similar levels of matrix wear. Metal ions, which are released during articulation, are likely to blame; however the effect of local metal ion infiltration on chondrocytes is largely unknown. We therefore utilized a tribological bioreactor to articulate bovine cartilage explants against a CoCr counterface, and then evaluated the tissue matrix for the presence of metal ions through x-ray fluorescence microscopy. We hypothesized that the deposition of Co and Cr can be detected at higher concentrations at the surface than in the deep zone of cartilage.

METHODS: Full thickness (~3 mm) oval articular cartilage explants were extracted from the femoral trochlear groove of six to eight month old bovine stifile joints using a custom punch. Testing was conducted in a tribological bioreactor, housed in an incubator with 95% humidity, 5% CO2 and 37 degC.

Three explants were confined in porous polyethylene scaffolds, and loaded with a 32 mm diameter CoCr ball. Applying a contact pressure of 2 MPa, the explants were articulated against a CoCr ball (ball rotation: ±30° at 0.5 Hz, explant rotation: ±15° at 0.1 Hz) for three hours or 5,400 cycles. Immediately after testing, samples were removed from their scaffolds and cut along the long axis through the center of the wear path. Individual halves were then flash frozen in liquid nitrogen, and stored overnight at -80 degC. Explants were then prepared with Optimum Cutting Temperature (O.C.T.) gel for cryostat sectioning. Samples were stored overnight at -20 degC in O.C.T. matrix, and 10μm sections were taken with a Leica CM3050S cryostat the following day. Immediately after sectioning, sections were affixed to custom sample holders designed for x-ray fluorescent microscopy, and were kept at -20 degC for 3 days until microscopy was performed at the synchrotron. Samples were raster scanned at 2-ID-E APS (Argonne National Laboratory) with 600 nm zone plate focused x-ray beam (10.35 keV). Overview fast scans were performed with 10 micron pixel size and high resolution slow scans were performed with 1 and 0.3 micron pixel size. Fluorescent spectrum was collected for each pixel with 50 milliseconds dwell time and analyzed using MAPS software with AXO thin film standard calibration. Images for P, S, Cl, K, Ca, Cr, Fe, Co, Cu, and Zn were obtained.

RESULTS: X-ray fluorescence mapping provided images of elemental distribution through articulated and deep layers of cartilage, where all elements were successfully imaged and concentrations could be determined. In the superficial zone of cartilage where samples were articulated, Co and Cr were uniformly distributed. Elevated levels of both Co and Cr were found when comparing the articulated surfaces to the non-contacted deep zones. In addition to the total increase in ion concentration, some sample locations contained metal hot-spots of 1-5 microns with a 4-5-times higher concentration of CoCr as compared to the surrounding areas.

DISCUSSION: We hypothesized that potentially harmful deposition of Co and Cr can be detected and evaluated using XFM. It worked for the determination of Co, Cr in concert with other element depositions in tissues with high sensitivity and without labeling, staining or any other tissue alterations, typically required by microscopy techniques. The deep zone of cartilage was not in direct contact with the CoCr head during articulation. The presence of ions in this area is thus due to the deep zone exposure to ions released into the media while the surface deposits represent ion concentrations due to direct contact. Previous data from our laboratory and others has shown high chrondrocyte death at the surface to articulation against CoCr, thus a future question could evaluate the role of cobalt and chromium ions in mechanisms of chrondrocyte death. Furthermore, the direct metal-on-cartilage interaction that occurs in hemiarthroplasty can lead to the formation of metal-protein complexes, which induce hypersensitivity responses from various cell types via the production of pro-inflammatory cytokines and chemokines.

Tribocorrosion science: new challenges and opportunities / 12

PLENARY TALK : Innovative Dual-Fuel Engines for Maritime Decarbonization—Challenges and Solutions

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Low-speed two-stroke engines have powered marine transportation for over a century and remain the standard propulsion system for marine transport due to their high efficiency and reliability. Today, as the maritime industry aims to reduce greenhouse gas (GHG) emissions to zero by about mid of the century, technological innovation is key to achieving a sustainable future.

As a leading developer of low-speed two-stroke engines, WinGD is committed to advancing the decarbonization of marine transportation by improving fuel efficiency, reducing emissions, and incorporating hybrid power technologies. Furthermore, WinGD develops dual-fuel (DF) engines capable of operating on alternative fuels, such as methanol and ammonia. These alternative fuels are expected to gain increasing relevance in the comingdecades, given their potential to significantly reduce or even eliminate CO_2 emissions from internal combustion engines. However, their adoption requires the development of new designs and processes to ensure continued safety, performance, and durability.

This presentation will outline WinGD's approach to decarbonization, with a focus on overcoming challenges related to the application of alternative fuels, such as ammonia's corrosive nature and its effects on lubrication.

Materials and mechanisms / 13

PLENARY TALK : Tribocorrosion in pressurized water reactors

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Framatome designs and manufactures pressurized water reactors. In 2023, 63% of electricity produced in France comes from nuclear reactors. Within the reactor, some components are subjected to wear, due to fluid excitation, and to movements of rods used to adapt the reactor's power.

The working environment of these components is pressurized water at high temperature with a dedicated chemistry (150 bars, 320 °C et the water contains boric acid (H3BO3) and lithium hydroxide (lithineLiOH) to adapt pH). The aim of boric acid in the water is to moderate the activity of fuel and is adapted along fuel life. It has been demonstrated that some components as Stellite 6 coated latch arms were subjected to tribocorrosion (1). This parameter mustbe considered in the life duration of components. Dedicated test benches have been developed to study tribocorrosion and PhD work engaged with EPFL (2).

(1) E. Lemaire, M. Le Calvar: Evidence of tribocorrosion wear in pressurized water reactors - Wear 249 (2001) 338–344

(2) These n° 6430 (2014), Sandra Guadalupe Maldonado: Tribocorrosion in pressurized high temperature water: a mass flow model based on the third body approach

Coatings and surface protection / 14

Tribocorrosion properties of borided and NbC treated coatings on Vanadis 6 cold-work tool steel

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The aim of our study is to evaluate the tribo-corrosion properties of conversion coatings on Vanadis 6 type of steel. Vanadis 6 cold work steel is a high-carbon, high alloyed steel known for its favourable mechanical properties even in very harsh operating conditions, including high loads, contact stresses, contact temperatures and severe wear [1]. Mechanical properties were recently reported to be improved by cryogenic treatment [2], while corrosion properties were reported to be improved by hard coatings [3].
In this study, two types of hard coatings, namely boron and Niobium coatings, were applaid to the Vanadis 6 substrate. These coatings improve the mechanical as well as corrosion properties of the

Vanadis 6 steel substrate. Tribocorrosion properties were studied using reciprocating sliding in different solutions. The tested solutions were 0.1 M NaCl and 0.0001 M NaOH, pH 13, and were then suited to better estimate tribocorrosion properties of tested materials. Different characterization methods were employed, including optical microscopy, SEM/EDS investigation of the worn surfaces, Raman spectroscopy, profilometry and Vickers hardness tester.
Tribocorrosion of passive materials such as stainless steels or titanium alloys has been widely studied during the last decades under different mechanical and electrochemical conditions in a wide range of corrosive electrolytes. Tribocorrosion of non-passivating or active materials is subjected to progressive dissolution [4]. In this study, a multi-step investigation and iterative refinement of the experimental approach was used to obtain representative data, in order to estimate the contributions of mechanical wear, corrosion, and tribocorrosion to total wear.

Tribocorrosion in CO2 atmosphere / 15

Root Cause Analysis of Cracking in MDEA Regenerator

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Purified gas is considered an important source of energy in the world. Mellitah Gas Complex consists of a Gas Treatment Plant composed of a Sulphur Recovery Unit. This system was commissioned in 2004. The effluent gases from the Claus plant are directed to a tail gas treatment system and incinerated to oxidize any residual sulfur to sulfur dioxide. Air regulations prohibit the discharge of large amounts of sulfur to the atmosphere. The Sulfur Recovery Unit Comprises a Methyldiethanolamine (MDEA) Regenerator to concentrate acid gas (H2S & CO2) before thermal reactor and Catalytic converter in Claus Unit. In 2019 the regenerator was inspected and found that it was suffering from several cracks or crack-like flaws on internal weld seams, and further investigation and inspection have shown an aggravated situation of the cracks specifically in CW-7 welded joint that have progressed to reach 11mm in depth on some spots on a 27mm plate.
This case study will identify the Root Causes Analysis (RCA) of the cracks and contributing factors that lead to the cracking phenomenon in the Regenerator. Course of action have been taken to achieve this target; A sample of metal was extracted from multiple locations around the regenerator and the welded joint CW-7, which is the most affected by the crack. Metallurgical study was conducted to address the RCA. The study was entirely based on experimental data and actual operations conditions (gas and liquid samples from different areas of the complex have been collected and analyzed). Process Parameters such as P, V, T data and flow rate were collected, and chemical treatment conditions including Amine Quality (Heat Stable Salts using Ion Chromatography (IC), Acid Gas load, MDEA Concentration, Chloride/Oxygen content, MDEA filtration) were examined. In addition, Corrosion Damage Mechanism that included metallurgical using Scanning Electron Microscopy (SEM) /Energy Dispersive X-ray Spectroscopy (EDS) analysis) and corrosion investigation using Non-Destructive Test (NDT) techniques such as magnetic particle examination (MT) and phased array UT (PAUT) were applied to show the behavior of cracks in the damaged area.
As results of the study: Metallurgical study showed that the crack propagating was mainly along the grain boundaries (intergranular) and was filled with deposits. There are many factors that could contribute to Amine Stress Corrosion Cracking, the inborn fabrication and welding defects are the most probable damage mechanism for the crack in the MDEA regenerator. Lean MDEA concentration is verry low (~30% wt.), however, the design philosophy advises keeping concentration at a minimum of 45–50 weight percent. Additionally, the chloride content in lean MDEA was very high content ~ 941 ppm(w) which can lead to future potential corrosion problems. To maintain lower chloride content (< 500 ppm), it should be ensured that a partial continuous blowdown is implemented to keep the feed of lean MDEA in the circuit along with monitoring the continuous injection of antifoam and corrosion inhibitor in the system. On the other hand, more contaminants were found in the lean MDEA solution which indicated the problem in the filtration unit, and it is suggested to install reclaiming skid to reduce the contamination and keep the fresh amine within the desire limit. The other side of problem is the makeup water quality due to presence of oxygen in the system, the analysis confirmed that there was about ~100 ppb of oxygen in the system and it seems that the main source is the demineralized water which having an oxygen concentration of 180 ppm,

suggesting that water deaeration shall be provided in the demineralized water production process to strip-off all dissolved oxygen in parallel of this action it's recommended to install an O2 and pH online analyzer around the amine and water makeup circuit. A secondary source of Oxygen might be the fresh amine itself. Furthermore, it is advised to apply suitable coating compatible with fluid media.

Tribocorrosion science: new challenges and opportunities / 16

Effect of hydrogen charging on tribocorrosion performance of C45CE steel

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Tribocorrosion of hydrogen-embrittled steel is a critical concern for materials used mostly in harsh environments, particularly in applications involving high mechanical stress and corrosive conditions. Hydrogen uptake by steel structures, induced by an electrochemical process, can cause degradation of mechanical properties and induce cracks. It is widely known as hydrogen embrittlement.
This study investigates the combined effects of mechanical wear and electrochemical corrosion on hydrogen-charged C45CE carbon steel, focusing on the degradation mechanisms. The tribocorrosion behavior of hydrogen-charged steel is evaluated through the tests in corrosive solutions, accompanied by microstructural analysis and hydrogen diffusion studies. The method of hydrogen charging in carbon steel was carried out electrochemically under galvanostatic conditions in a 1M Na2S solution for 24 hours. The tribocorrosion tests were done in a reciprocating tribometer with a ball on a flat configuration using a 6 mm Al2O3 ball as a counterpart and an applied load of 2.6 N. The selected electrochemical conditions for the tribocorrosion tests were two applied potentials in the cathodic -1.5 V (MSE) and passive -0.5 V (MSE) domain of the steel in a borate solution. The duration of all the tests was 30 minutes with a wear track length of 4 mm. Surface and subsurface characterization of the worn surfaces was carried out after the tests to elucidate the degradation mechanisms.
Results show that there is no effect of hydrogen on the hardness of the hydrogen-charged samples. However, there was a decrease in the fracture energy when the same charging method was applied to Charpy samples. Hydrogen charging does neither modify the grain structure of the steel. The tribocorrosion results show that the hydrogen intake has an impact when no passive layer is formed on the steel (cathodic conditions). In that case more smearing on the charged sample surface was observed with higher subsurface recrystallization. On the other hand, under passive conditions, no difference was observed in the worn area of the steel, indicating that the passivation conditions govern the tribocorrosion response of the steel.

Tribocorrosion in CO2 atmosphere / 17

PLENARY TALK : Sustainable Corrosion and Erosion Control: From Inhibitors to Novel Technologies

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One persistent issue that plagues carbon abatement and energy sectors is infrastructure degradation through corrosion. Currently, the most popular method of internal corrosion control for carbon steel

infrastructure consists of the application of corrosion inhibitors which suppress corrosion through surface adsorption. This technology is well-established, being relied upon in both traditional energy industries, as well as emerging areas, such as geothermal and carbon capture, utilisation and storage. Despite its advantages, the application of corrosion inhibitors has various technical constraints, as well as environmental and economic challenges.
This presentation provides an overview of current activities at the University of Leeds which have supported the optimisation of corrosion inhibitors, as well as alternative, (and in some instances quite speculative) strategies to reduce our reliance on inhibitors. Interestingly these new technologies hold potential to mitigate erosion, as well as corrosion processes.

Electrical and energy systems / **18**

Tribological performance of polymer compounds in gaseous hydrogen

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In this study, friction and wear of conventional and alternative high performance polymer compounds for compressors were investigated in gaseous hydrogen and nitrogen up to 80 bar of gas pressure. The compounds used were a commercial PEEK matrix with 10 wt.% each of PTFE, graphite, and short carbon fibres (Polytron), a PPS matrix with 10 wt.% each of PTFE and graphite (MOCOM), and an experimental PA12 matrix with PTFE, chemically coupled with an oleyl alcohol, as additive (supplied by the polymer research institute IPF). For all compounds a steel counter disc (type 316L / 1.4404) with a lapped surface finish was used in a cylinder-on-disc setup.

Due to the cylindrical shape of the polymer samples, the contact area and pressure change if wear occurs. Therefore, experimental results of pre-screening tests have been used as input for FEM and an analytical model to determine the decreasing contact pressure over time. Afterwards, the outcome of the models was used to determine the duration of the experiments to reach typical contact pressures of seals in hydrogen compressors.

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Erosion-corrosion and fatigue corrosion / **19**

A new lab scale multidegradation test rig to study the effect of fatigue bending on the tribocorrosion performance of austenitic stainless steel

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Tribocorrosion often occurs in conjunction with fatigue in engineering applications, leading to a material multidegradation phenomenon. This interaction has been extensively investigated, particularly within the oil and gas industry, where different grades of stainless steels have been tested under diverse tribocorrosion-fatigue conditions. The underlying mechanisms governing the interaction between fatigue loading and tribocorrosion are influenced by multiple factors, including the alloying composition of the material. However, the predominant factor appears to be the specific nature of the applied fatigue loading. More recently, this degradation process has gained increasing relevance in emerging offshore applications, such as Offshore Renewable Energy (ORE) systems, which are subjected to similar environmental and mechanical stressors.
In this study, we present findings from the "MORE" project, funded by the EU through the Clean Energy Transition Partnership (CETP). This project aims at standardizing small- and large-scale multi-degradation testing systems for the ORE industry. The project's objective is to establish an accelerated pathway for the validation of materials used in the offshore renewable energy sector. For this purpose, a small-scale multi-degradation test rig (SSMD) was designed, prototyped, and built to study different metallic materials and coatings (used in ORE systems) in a tribocorrosive set-up under four-point bending fatigue loading. Austenitic Stainless Steel (316L) was chosen for the initial trials focusing on the effect of static and cyclic bending on the tribocorrosion behavior.

Coatings and surface protection / 20

Tribocorrosion response of PVD Mo-N coated Ti-6Al-4V

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KEYWORDS: Coatings, Molybdenum nitride, Physical vapour deposition, Ti-6Al-4V alloy, Tribocorrosion, Magnetron sputtering

INTRODUCTION
Driven by factors such as sedentary lifestyles and age-related degeneration, the increasing prevalence of musculoskeletal disorders has heightened the need for innovative orthopaedic solutions [1]. Biomedical alloys, meticulously designed to operate within the complex and demanding environments of the human body, have transformed medical technologies. Titanium alloy, Ti-6Al-4V is a widely used biomedical material, valued for its biocompatibility, high corrosion resistance, and high specific strength (strength to weight ratio) [2]. However, its poor tribocorrosion performance limits its use for bearing surfaces in human joint replacements [3], [4], [5]. This issue can be addressed by applying hard biocompatible coatings to the Ti-6Al-4V surfaces [6], [7], [8]. Of these, titanium nitride (TiN) and diamond-like-carbon (DLC) coated Ti-6Al-4V have previously been evaluated in-vivo. The latter has proven problematic due to premature blistering and coating loss, whilst the former is used only in very limited quantity. Of alternative coating materials (for application to Ti-6Al-4V) those based on Mo-N compounds appear promising [9].
Molybdenum, a key component of Mo-N coatings, plays a vital role in human biological processes, primarily existing as bioavailable molybdate anions [10]. These anions are essential for critical enzymatic functions [10]. In physiological solutions, molybdenum dissolves without significant concerns, with the human body maintaining homeostatic regulation at levels of 10 to 15 mg [11]. Recommended dietary intakes suggest an allowance of 45 to 50 μg molybdenum per day for adults [12], [13]. Mo-N has a closed-packed metallic structure in which nitrogen occupies the interstitial sites [14]. Its bonding is predominantly strong polar covalent bonding resulting in high bulk moduli and mechanical hardness [15], [16]. These attributes make Mo-N a potential candidate for the protection of biomedical implants, not only by reducing alloy degradation but also by offering a more

predictable and controllable biodegradation profile [17], [18], [19]. Given that molybdenum is naturally regulated in the human body at trace levels, the concept of leveraging nitrogen to modulate its dissolution introduces a compelling approach for enhancing implant performance while ensuring the controlled release of degradation products.
This study characterised and investigated the corrosion and tribocorrosion behaviour of Mo-N coatings deposited on Ti-6Al-4V at two different nitrogen partial pressures. By subjecting the coated samples to conditions simulating physiological solutions, this work aimed to replicate in vivo conditions to better understand the performance of these coatings in terms of both tribocorrosion resistance and controlled degradation.

METHODOLOGY
Mill-annealed, extra-low interstitial grade 5 Ti-6Al-4V rods (Brindley Metals, UK) were cut into circular coupons using Struers Accutom-10 precision cutter (Struers Inc., Denmark). Samples were ground and polished to a mirror finish and ultrasonically cleaned. Mo-N coatings were deposited onto these samples via reactive close-field unbalanced magnetron sputtering using a custom-built PVD coating facility (Boride Services Ltd., UK). Two coating deposition runs, C1 and C2, at nitrogen partial pressures of 0.021 Pa and 0.043 Pa were carried out.
The coating thickness was measured using a Tecvac ball cratering calo tester (Tecvac Ltd., UK) and by a direct measurement of a polished cross-section taken perpendicularly using a Zeiss field emission scanning electron microscope (SEM) with a Gemini II Column (Carl Zeiss Microscopy GmbH, Germany). Semi-quantitative elemental analysis of the coating composition was achieved with an energy dispersive X-ray spectroscopy (EDS) detector (EDAX Ametek Inc., USA). NanoMap-500LS surface contact profilometer (AEP Technology Inc., USA) equipped with a stylus having a tip radius of 1 μm was used to measure the surface roughness. Zeiss Axioscope 5 light optical microscope (LOM) (Carl Zeiss Microscopy GmbH, Germany) facilitated topographic examination at different magnifications. Structural analysis was assessed via X-Ray diffraction (XRD) using a Rigaku Ultima IV diffractometer (Rikagu Corp., Japan). Mechanical properties were evaluated using a Micromaterials NanoTest 600 Nanotester (Micromaterials Ltd., UK) through nano-indentation (Berkovich indenter, 20 mN load) and nano-scratch testing (conical indenter, 450 mN max load).
Potentiodynamic corrosion testing was performed in Ringer's solution at 37 ± 1℃ following ASTM G5-14 and ASTM G5-94 standards [20], [21]. Tribocorrosion behaviour was studied using a custom-built reciprocating sliding tribometer (University of Malta, Malta) connected to a three-electrode cell set up with a Gamry Reference 1000 potentiostat (Gamry Instruments Inc., USA). Tests involved reciprocating sliding under open circuit potential (OCP) and anodic potential (AP) conditions of 100 mV vs. SCE, using a 12.7 mm alumina test sphere counterface with a 3 N load (688 MPa max Hertzian pressure) for a stroke length of ~6.4 mm at a frequency of 1 Hz, creating a bidirectional ball-on-disc movement. Tests were carried out at a temperature of 37 ± 1℃.
The mechanistic approach proposed by Uhlig [22] was implemented under AP conditions to calculate total tribocorrosion volume loss, V, as the sum of mechanical wear, V_{mech}, and wear due to chemical oxidation V_{chem} [22]. V_{chem} includes wear-accelerated and passive corrosion, determined using Faraday's second law. For these computations, the theoretical density of Mo-N was estimated using the NaCl prototype crystal model [23]. Valence states for Ti-6Al-4V and Mo-N were determined from oxidation reactions. As suggested in the Pourbaix diagram for molybdenum [10], at a pH of 7.4 and a potential of +100 mV vs. SCE, Mo-N oxidizes to molybdate anion (MoO_4^{2-}) and nitrogen gas (N_2). While this approach captures the main oxidation pathway, it is limited in the account for potential intermediate oxidation states or competing reactions, such as oxygen evolution.

RESULTS AND CONCLUSIONS
Reactive magnetron sputter deposition was used to apply two coatings, C1 and C2, at two different nitrogen partial pressures, 0.021 Pa and 0.043 Pa, respectively. C1 exhibited intensity peaks corresponding to Im-3m (229) Mo and Fm-3m (225) MoN whilst the diffraction pattern of C2 matched reflections for Fm-3m (225) MoN phase. Both coatings had a thickness of ~4 μm. The R_a values of C1 and C2 were 25.8 ± 2.1 nm and 17.9 ± 3.5 nm, respectively, compared to 5.9 ± 2.1 nm for the untreated Ti-6Al-4V. The SEM surface topography of the as-deposited coatings exhibited a fine topography, characterised by uniformly distributed dome-tipped asperities indicative of consistent nodular PVD growth [24]. SEM images of fractured C1 and C2 cross-sections displayed a dense columnar fibrous structure, with no apparent voids synonymous with a Zone T structure, according to Thornton's structural zone model [25], [26], [27].
The nano-indentation hardness values for C1 and C2 were 36.2 ± 2.0 GPa and 38.2 ± 1.8 GPa respectively, both much harder compared to 5.8 ± 0.1 GPa for the Ti-6Al-4V substrate. Molybdenum has an electronegativity of 2.16 and nitrogen has an electronegativity of 3.04, leading to predominantly

strong polar covalent bonding, which results in such high hardness [15], [16]. During nano-scratch tests the untreated Ti-6Al-4V underwent gross plastic deformation and ploughing of the material which build up in front of the indenter. In contrast, C1 and C2 were resilient to plastic flow, with no signs of delamination or surface plastic deformation. Excellent adhesion between the coating-substrate interface is attested.
The total surface material losses due to tribocorrosion, produced when sliding against an Al_2O_3 test sphere under elastic contact conditions, under both OCP and AP conditions are significantly higher for the untreated Ti-6Al-4V substrate compared to the coated samples. Under OCP conditions, the untreated Ti-6Al-4V resulted in a TVL of 108.88×10^{-12} m³, whereas C1 and C2 exhibited substantially lower values of 0.15×10^{-12} m³ and 0.76×10^{-12} m³, respectively. Similarly, under AP conditions, the TVL for the untreated Ti-6Al-4V was 143.37×10^{-12} m³, while both C1 and C2 had a much lower TVL of 1.82×10^{-12} m³ and 1.50×10^{-12} m³, respectively.
The average coefficient of friction, under OCP was ~0.33, 0.28 and 0.15 for the uncoated, C1, C2 and uncoated Ti-6Al-4V respectively, whilst under dynamic positive AP it was ~0.31 for the uncoated test-piece and ~0.35 for both coated materials. Under the latter conditions the dynamic corrosion current recorded was below 30μA for the coated materials which was lower to that recorded for the uncoated Ti-6Al-4V of ~130μA. The volumetric total material loss was often more than one order of magnitude less for the coated titanium alloy compared to the uncoated titanium. There was microscopy evidence of surface scratching produced via micro abrasion of coatings whilst many of the uncoated surfaces showed cyclic damage due to the removal and repassivation of the TiO_2 passive layer as well as mechanical wear by superficial plastic deformation of the surface asperities, abrasive wear, and adhesive transfer.
Chetcuti [28] reported the tribocorrosion behaviour of untreated CrN/S (where CrN is the outer layer and S-phase is the inner layer) tribopairs on wrought CoCrMo. In her work, Chetcuti computed the TVL, following reciprocating sliding at 1 Hz with an applied normal load of 3 N in Ringer's solution, under both OCP and AP conditions. All parameters and equipment used in her work are identical to this study and hence comparable [28]. Under OCP, CrN/S lost a TVL of 0.44×10^{-12} m³, whereas under AP, CrN/S lost a TVL of 0.41×10^{-12} m³. Under OCP conditions, CrN/S proves to offer better tribocorrosion performance than C2. However, C1 shows better resistance to tribocorrosion wear than CrN/S as the TVL of CrN/S is ~3 times greater than the TVL of C1. Under AP conditions, CrN/S offers better wear resistance than both coatings, with less than ~0.25 the TVL for the same duration of sliding, under the same parameters. Under OCP measured TVL of the C1 and C2 thin films are comparable with those of CrN/S, suggesting that Mo-N coatings are also resistant against Type I corrosion wear showing promising results for tribological applications [24], [29], [30], [31]. Under AP, Mo-N experienced more material losses, which however are less detrimental than CrN. C1, with a lower nitrogen content, showed increased dissolution compared to C2, which has more molybdenum, indicating nitrogen can modulate dissolution. This holds promise for biomedical applications as it suggests minimal release of foreign Mo debris into the biological environment, enhancing biocompatibility and minimising the risk of adverse tissue reactions [32]. With controlled degradation, the coatings are likely to maintain their integrity and performance over time, ensuring the longevity and functionality of biomedical alloy implants [32], [33].
In conclusion, Mo-N coatings deserve further investigation under more advanced in-vitro tribocorrosion conditions and should be directly compared with CrN coated Ti-6Al-4V.

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Erosion-corrosion and fatigue corrosion / 21

Erosion-corrosion performance of nickel aluminium bronze alloys in marine environments: recent developments

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Erosion-corrosion performance of nickel
aluminium bronze alloys in marine environments: recent developments

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Abstract

Nickel Aluminium Bronze (NAB) is a common alloy used in seawater cooling of power stations and onboard vessels as well as seawater handling and marine propulsion systems and is now being considered for offshore tidal and wave energy capture systems. However, although standards for casting NAB are used to minimise selective phase attack the performance under erosion-corrosion is often sub-optimal reducing service lifetimes and efficiency of pumps and propulsors. These lead to expensive maintenance of systems and reduced fuel efficiency. As the marine industry moves to net zero and decarbonisation; the improvement of asset lifetimes and reducing fuel usage are key to achieving national and global targets. Therefore, this paper reviews recent research into erosion-corrosion of nickel aluminium bronze with attention to surface state and surface - environment interactions, for example [1-9]. Both solid particle and cavitation erosion-corrosion are reviewed with a focus on the surface condition of NAB prior to testing including the effects of shot peening, compressive surface stresses, pre-exposure by long term seawater immersions, influence of oxide films. The influence of deposition techniques such as surface welding, stir welding, electroplating and the effects of adding Cr into friction stir welded NAB as well as Ce, Sm and Yb additions into as-cast NAB.

Techniques such electrochemical noise looking a selective phase attack and the influence of sulphide concentration on performance are discussed. Recent work by the authors on cavitation erosion-corrosion mimicking the switching from static-dynamic seawater environments seen by marine propulsion systems will be detailed and the consequence for long term service will be addressed. The importance of understanding the mechano-electrochemical-microstructural interactions are highlighted. Data from recent literature are used to rank the performance of surfaces produced by different manufacturing/deposition processes and to update synergy values mapped against the ratio of mechanical to electrochemical contributions to surface loss. The role of corrosion of anodic phases/microstructure in tribocorrosion are also discussed and the state-of-the-art of current understanding will be outlined along with future research needs.

[1] Corrosion and Cavitation Erosion Behaviours of Cast Nickel Aluminium Bronze in 3.5% NaCl Solution with Different Sulphide Concentrations
[2] Effects of Ce, Sm and Yb on cavitation erosion of NAB alloy in 3.5% NaCl solution - PMC
[3] Effect of Oxide Film on the Cavitation Erosion-Corrosion Behavior of Nickel-Aluminum Bronze Alloy - ProQuest
[4] Effect of compressive stress on cavitation erosion-corrosion behavior of nickel-aluminum bronze alloy - PMC
[5] Biofouling and corrosion rate of welded Nickel Aluminium Bronze in natural and simulated seawater
[6] A Study of Erosion–Corrosion Behaviour of Friction Stir-Processed Chromium-Reinforced NiAl Bronze Composite - PMC
[7] Synergistic improvement of erosion-corrosion resistance and mechanical properties of nickel aluminium bronze alloy by the addition of Cr | Rare Metals

[8] Understanding the Corrosion Behavior of Nickel–Aluminum Bronze Induced by Cavitation Corrosion Using Electrochemical Noise: Selective Phase Corrosion and Uniform Corrosion - PMC
[9] Erosion-corrosion behavior of Ni-Al-Cu coating on nickel-aluminium bronze alloy in 3.5 wt% NaCl solution - ScienceDirect

Materials and mechanisms / 22

Tribocorrosion behaviour of noble alloys

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Gold is considered a noble metal due to its chemical inertness and resistance to oxide formation within the stability potential window of water. However, gold is very soft, and it is commonly alloyed with other metals (copper, silver, zinc) to improve its mechanical properties. The use of less noble alloying elements such as copper or silver, may lead to a preferential dissolution of those elements and potentially modifying the original properties of the gold alloy. Above the risk of selective dissolution, which has been previously studied, when gold alloys are subjected to a tribological contact in a corrosive environment, tribocorrosion degradation may occur. This talk aims at assessing the tribocorrosion behavior of a gold alloy during sliding against an alumina counterpart in a NaCl electrolyte. To do that, a ball on flat configuration was used under well controlled mechanical (1.5N normal load and 10 mm/s sliding speed) and electrochemical (Open Circuit Potential conditions and applied potential) conditions. After the tribocorrosion tests, 3D confocal microscopy, Scanning Electron Microscopy (SEM) and Auger Electron Spectroscopy (AES) was carried out to quantify wear and identify the degradation mechanisms.
During the tribological contact, gold alloy plastically deforms and ploughs. Wear occurs during the first cycles and once a certain deformation is reached, the cyclic sliding generates material smearing and a decrease in wear. On the other hand, at the onset of sliding a potential decay of around 150 mV was observed in the tests carried out at OCP and a current increase under potentiostatic conditions. This indicates a wear accelerated corrosion of the gold alloy by the mechanical action. At the end of the tribocorrosion tests, the worn surfaces showed an enrichment in gold and a high copper depletion over more than 20 nm of depth. The wear patterns were interpreted by a mechanism of mechanical mixing which continuously brings copper to the surface and preferentially dissolves.

Electrical and energy systems / 23

Water-Based Lubricants in Power Tools for Construction: Tribological Performance and Corrosion Challenges

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The study investigated a water-based lubricant specifically designed for power tools, such as diamond drilling tools used in the construction industry. The water content in the lubricant enhances heat transfer capabilities and provides superlubricity, thereby improving thermal management and gearbox efficiency during operation. The formulation was evaluated using standardized ASTM laboratory tests and custom-designed accelerated corrosion tests that simulate the conditions within gearboxes of high-performance tools. While laboratory conditions indicated modest corrosion risks, the real-application benefits of effective lubrication and enhanced cooling appear to outweigh these

concerns. Additionally, the study addresses the challenges of sealing water-containing lubricants with FKM and NBR radial shaft seals. Future research is recommended to further optimize traditional sealing systems to ensure reliability in demanding environments.

Bio-tribocorrosion and related phenomena / 24

Elucidation of tribocorrosion and repassivation dynamics of stainless steel

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Tribochemical processes occur in various environments, where the combination of mechanical stress and chemical reactions can lead to significant changes in material properties, surface composition, roughness and technological performance. A detailed observation of chemical and mechanical tribodegradation, as well as materials repassivation are difficult to asses in-situ. Our main objectives in this work were to enable mechanistic insights into tribocorrosion and a comparison of repassivation dynamics following electrochemical and mechanical removal of an oxide. We therefore developed a new electrochemical flow cell with in-situ surface scratching combined with elemental analysis using inductively coupled plasma mass spectrometry (ICP-MS). When combined with post measurement imaging, this facilitates both qualitative and quantitative assessments of the electrochemical and mechanical removal of material, and allows a quantitative characterization of repassivation.
Experiments conducted on a stainless steel sample, Fe(82.5)Cr(17.5), demonstrated excellent reproducibility. Due to tribomechanical damaging, repassivation of damaged areas showed considerably faster first order reaction kinetics and higher dissolution rates, compared to electrochemical passivation. During the scratching process, both ions and particles were generated. While high Cr-content (≥ 12%) facilitates full repassivation, low Cr-content (< 12%) samples are unable to form a stable passive layer under tribocorrosive conditions. This technique is directly applicable for analyzing complex tribochemical processes, which can apply to a wide range of available engineering materials.

Electrical and energy systems / 25

IMPACT OF TEST ENVIRONMENTS ON POLYMER TRIBOLOGICAL BEHAVIOURS UNDER RECIPROCATING SLIDING FOR HYDROGEN APPLICATION

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The deployment of hydrogen as a sustainable alternative to fossil fuels demands the use of materials that can ensure safety, durability, and performance across a range of operating conditions. Thermoplastic polymers are increasingly used in hydrogen infrastructure and components due to their

chemical stability, low weight, and processability. However, their tribological performance specifically friction and wear behaviour in hydrogen environments remains insufficiently characterized, particularly under reciprocating motion, which is common in seals, valves, and actuators.

This study investigates the effect of different test environments ambient air, dry air, nitrogen, and gaseous hydrogen on the tribological behaviour of three polymer composites: carbon fiber, PTFE and graphite filled PEEK (PEEKCFGrTF), PPS (PPSCFGrTF), and graphite filled polyimide composite (PI3GR). Tests were conducted using a reciprocating pin-on-disc configuration against a mirror-polished 316L stainless steel counterface, simulating conditions relevant to hydrogen system components.

Preliminary findings show that environmental conditions significantly affect both friction coefficients and wear rates, with hydrogen and dry environments generally reducing friction but exhibiting material-specific effects on wear. The results underscore the importance of simulating operational atmospheres when assessing polymer suitability for hydrogen applications.

Tribocorrosion science: new challenges and opportunities / 26

New challenges and prospectives for tribocorrosion science

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The description of tribocorrosion phenomena and mechanisms through tailored experimental approaches and theoretical models has allowed gaining understanding in the response of materials operating under different tribological contacts in reactive environments. At present, the complex interactions between chemical and mechanical phenomena have been rationalized through comprehensive models (analytical and numerical) mainly for passive materials assuming that wear is the consequence of plastic deformation of asperity contacts. Other situations, when third bodies are formed as in the case of high temperature conditions, have been also described by considering wear as a mass flow and not simply a material loss.
New technological challenges in terms of extreme environments (i.e. hydrogen, ammonia, low speeds, high temperature), materials (composites, multiphase, multicomponent, multilayer) or lubrication methods (water based, gels) requires for a deeper understanding of the link between the involved chemical, mechanical and material phenomena. In particular, the interaction between surface properties (including chemistry but also microstructure) and wear, friction and lubrication as a function of mechanical and chemical conditions needs to be further described.
In this talk, an overview of the scientific questions to be addressed in the field of tribcorrosion will be presented. Several case studies will be used to illustrate future advances in tribocorrosion science.

Bio-tribocorrosion and related phenomena / 27

Tribocorrosion behaviour of CoCrMo in simulated body fluid with applied potential

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CoCrMo alloys have been widely used as implant materials due to their excellent combination of mechanical strength, corrosion resistance and biocompatibility. However, the release of wear debris

during service can trigger inflammatory responses in peri-implant tissues, while reactive oxygen species (ROS) generated by the immune response to bacterial infections may alter surface chemistry and wear behaviour. The formation of tribofilms and the accompanying microstructural changes of CoCrMo under electrochemically controlled conditions are not yet fully understood. In particular, the correlation between applied electrochemical potential, tribofilm formation and subsurface microstructural evolution remains unclear.
In this study, we present a detailed investigation of surface microstructural and chemical changes during tribocorrosion tests under different applied potentials, with particular attention to tribofilm formation and surface deformation. Quantitative analysis of surface deformation was performed by measuring the geometrically necessary dislocation (GND) density mapped using precession electron diffraction (PED). A clear correlation between wear rate and surface strain was established. However, the relationship between tribofilm formation, surface strain and the applied potential was more complex.

Tribocorrosion in CO2 atmosphere / 28

Unvealing tribocorrosion mechanisms in CO2 anoxic environments: Insights from carbon steels and corrosion-resistant alloys

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Tribocorrosion in CO2 in anoxic environments remains poorly understood, despite its relevance in critical sectors such as oil and gas, geothermal energy, and carbon capture and storage (CCS). While CO2 corrosion mechanisms of metals have been widely researched over the past decades, the additional influence of sliding motion on surface degradation and tribocorrosion wear has received limited attention. Most of the existing studies dealing with CO2 tribocorrosion focus on erosion-corrosion due to particle impingement, while the effects of tribological loading in CO2-saturated media remain largely unaddressed.
The present work reveals the degradation mechanisms induced by sliding motion in CO2-containing aqueous environments, focusing on low-carbon steels, corrosion-resistant alloys, and Ni-based coatings. In case of low-alloyed carbon steels, CO2 corrosion leads to the formation of iron carbonate scales that partially protect the substrate by limiting diffusion of CO2. However, sliding disrupts this scale, producing the formation of a complex microstructure characterized by the presence of nanocrystalline grains, localized corrosion and compacted corrosion products. This microstructure ultimately leads to crack propagation and delamination. In corrosion-resistant alloys, sliding causes a cathodic shift in open circuit potential (OCP), indicating depassivation by rupture of the passive film, whereas in Ni-based cermets coatings the OCP remains stable suggesting no changes in electrochemical properties of the wear track. Surprisingly, Ni–P coatings show under sliding a potential shift towards anodic values, suggesting ennoblement of the wear scar.
These findings highlight the complex interplay between electrochemical and mechanical processes in CO2 anoxic environments. Standardized testing approaches based on either wear or corrosion alone may lead to misleading material selection. A more integrated tribocorrosion approach is essential to ensure long-term performance and safety.

Erosion-corrosion and fatigue corrosion / 29

Tribocorrosion in mining industry

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