Junge Tribologen

GfT Gesellschaft für Tribologie e.V.

5th Young Tribological Researcher Symposium

YTRS

21st - 22nd of June 2022

online and at MikroTribologie Centrum µTC

Patron:

M. Dienwiebel

Program and organization:

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Conference Program

Preface

For two long pandemic years, our personal and professional life as well as academic exchange was governed by restrictions, without the important personal chatting, intermission talks, or pleasant discussions in the lunch breaks or at the conference dinner. Therefore, it gives us great pleasure that, after a cancelled year and a year with online format, the 5th Young Tribological Researcher Symposium (YTRS) can now be held again in a partially presence form (hybrid). We are confident that this forum combines the advantages of both, providing plenty of space for face-to-face interaction under safe conditions, as well as virtual access and maximum flexibility at the same time. Thus, the symposium will provide young researchers and professionals from around the world with a platform to present and discuss their new topics and ideas or ongoing research projects. With a total of almost 30 presentations, we are delighted to offer the largest number in the YTRS history as well as an exciting and diverse program with topics ranging from molecular dynamics simulation to the investigation of entire drive trains. The topical presentations will be flanked by an informative seminar, an interesting excursion, and an evening event in relaxed atmosphere.

We will be happy to welcome you to the 5th YTRS and are looking forward to a great event!

Content

Program overview

Tuesday, 21. June 2022

08:30 - 09:00	**Opening and welcome** J. Eickworth, C. Morstein, F. Rummel *Working group "Young Tribologists",* *German Society for Tribology (GfT)* M. Scherge, M. Dienwiebel *Fraunhofer Institute for Mechanics of Materials IWM*
09:00 - 10:20	**Presentations of session "Machine elements and drive technology I"**
10:20 - 10:40	***Coffee break***
10:40 - 12:20	**Presentations of session "Machine elements and drive technology II"**
12:20 - 13:30	***Lunch break***
13:30 - 15:30	**Presentations of session "Lubricants"**
From 16:00	**Excursion** IAVF Antriebstechnik GmbH
From 19:00	***Dinner and get together***

Wednesday, 22. June 2022

08:30 - 10:50	**Presentations of session "Lubrication and material engineering"**
10:50 - 11:20	***Coffee break***
11:20 - 12:30	**Presentations of session "Coatings and surface technologies"**
12:30 - 13:30	***Lunch break***
13:30 - 14:50	**Presentations of session "Biotribology and life sciences"**
14:50 - 15:15	***Coffee break***
15:15 - 16:00	**Seminar: The rocky trail to Superlubricity** *M. Dienwiebel,* *Fraunhofer Institute for Mechanics of Materials IWM*
16:00 - 16:30	**Best presentation award and symposium closing**

Tuesday, 21. June 2022

Session “Machine elements and drive technology I”

09:00 **Presentation 01**

Tribological investigations on the radial shaft seal under the influence of the countrary surfaces and different relative velocities

Lin Yongzhen – TU Bergakademie Freiberg

This work asks after a methodologically representable relation between different contrary surfaces, relative velocities and the tribological behavior of the radial shaft seal (RWDR). The usage of a RWDR is usually as a dynamic seal element between the casing and the gear shaft. The appropriate application of RWDR is depending on different boundary conditions. It is recommended that the RWDR, the contrary surface and the operating condition should be matched in a tribological system. The considerations are limited on the one hand according to the DIN standard 3760, on the other hand depending on the application area of the RWDR. The contrary surface structure and the material of the shaft significantly influence the formation of the lubricating film between the shaft and the seal and thus the tightness of the RWDR. A specifically established RWDR test station at the IMKF institute is available for the experimental examinations. Among other standard contrary surfaces, 3D printed components are used as a replacement. The aim of this work is setting up a basis for the future researches regarding optimization options for wear reduction and service life extension of the RDWR, and gaining new insights for the replacement of 3D printed contrary surfaces.

09:20 **Presentation 02**

Assessment of tribological systems by lubricant monitoring

Malte Schütte – Fraunhofer Institut für Werkstoffmechanik IWM

With the increasing size and more isolated location (farther from shore) of wind turbines, remote diagnostics and on-demand maintenance become increasingly important. Gearbox-related failures are by far the most expensive failures. An improvement in this sector therefore leads to a significant reduction in costs. To be able to assess the condition of gearboxes and bearings before damage occurs, the focus is not only on sensors that measure the consequences of damage (particle sensors and vibration sensors), but also on sensor technology that looks at the condition in terms of time and cause before this damage occurs. For this purpose, the lubricant is monitored directly by FT-IR. In combination with the tribological measurement data, the probability of failure including the cause of failure is to be determined. For this purpose, the relationship between various influences and the condition of the system will be investigated and described, also using multivariant analysis methods. In this way, a chain of cause and effect for

failures of wind turbine or rolling contacts in general will be developed. This presentation gives the status of these investigations and is intended to provide an outlook on how the knowledge gained can be used in the future.

09:40 **Presentation 03**

Investigation of an axial plain bearing as a release bearing in a high-speed clutch in a vehicle drive system

Alexander Sutschet – Karlsruher Institut für Technologie (KIT)

In electromobility the trend is towards fast-moving drives. Previous research has shown that increasing the speed to 30,000 rpm can significantly increase the power density of traction drives. A multispeed transmission is then required to cover the power requirements at the wheel. As part of a consortium project, a powershift-capable high-speed clutch was developed together with partners from industry, which enables gear changes in a corresponding transmission. This contribution deals with the investigation of the disengagement system of this high-speed clutch. Ensuring the operability of the actuation system of the high-speed clutch is the primary objective of the investigation. Under the conditions outlined above, an axial plain bearing was developed as a release element. For its investigation, a special environment was developed, which now enables investigations of the sliding bearing at up to 20,000 rpm with targeted setting of different pressures. These two variables were varied to create stress collectives with which the plain bearing was subjected. Criteria for evaluating the release bearing behavior and condition in operation is for example the temperature. This contribution shows that axial plain bearings are suitable as disengaging elements in high-speed clutch systems and save both costs and installation space.

10:00 **Presentation 04**

Multi Scale Analysis of Friction Induced Vibrations on a Disc Brake System

Arn Joerger – Karlsruher Institut für Technologie (KIT)

Friction induced vibrations such as brake squealing or juddering are still challenging topics in product engineering processes. So far, this topic was particularly relevant for the automobile industry because they were the main market for disc brake systems. However, since mobility habits change, disc brake system are more often to be found on bikes or e-scooters. In all of these systems, vibrations are excited in contacts on micro scale but affect the user comfort and safety on macro scale. Therefore, the aim of this cross-scale method is to analyze a system on micro scale and transfer the excitation mechanisms on a macro scale system. To address both scales,

Session "Machine elements and drive technology I"

the current work presents on the micro scale a finite element model for the determination of the coefficient of friction, which is transferred to the macro scale and used in a multi body simulation. Finally, a finite element modal analysis is conducted, which allows to evaluate the brake system behavior on base of an excitation.

10:20 **Break**

Session "Machine elements and drive technology II"

10:40 **Presentation 05**

Numerical Estimation of Ionic Charge Density Transport out Numerical optimization of high-loaded microtextured contacts: understanding and mastering complexity

C. Orgeldinger – University of Bayreuth

Due to the war in Ukraine and the associated energy-related effects on the European market, the demand for efficient and sustainable technical products continues to accelerate. The optimization of friction-reduced tribological contacts can make an important contribution here. In high-loaded contacts with a high sliding portion, friction can be reduced in certain applications by textured contact partners, provided that the textures are correctly designed. To reduce the experimental effort, numerical approaches are often used to optimize texture geometry and arrangement. However, describing the contact conditions as detailed as possible quickly leads to a high computational effort if the experimental designs needed for the optimization are to be simulated. In this work, starting from a detailed simulation model for the computation of textured elastohydrodynamic cam-tappet contacts, it will be investigated to what extent the reduction of the model complexity affects the texture pattern resulting from the optimization. Based on the different modeling strategies, an estimation is made as to which simplifications of the model can be made in order to reduce complexity and computational effort while maintaining the same result quality as far as possible.

11:00 **Presentation 06**

A Numerical Analysis of the Conformal Hard EHL Contact

Ferdinand Schmid – Technical University of Munich

Conformal elastohydrodynamically lubricated (EHL) contacts occur when a lubricated tribosystem consists of a convex and concave solid body. Although it often occurs in practical applications, e.g. in internal gear stages

of planetary gears, the specific aspects of conformal EHL contact have been rarely studied in literature. In general, the contact area of two surfaces with different radii is not even but curved instead, which yields in a curved lubrication gap for conformal EHL contacts. In this study, a numerical model is applied to analyze dimensions of the contact curvature , micro slip and friction force of an EHL conformal contact considering non-Newtonian fluid behavior and thermal effects. The model is further applied to analyze the influence of operation conditions such as load or velocity. A conformal contact yields in higher radii of curvature of Hertzian contact and thus for the same normal force in greater contact area and lower contact pressure compared to contraformal contacts. It is shown, that for the case of equivalent normal force as well as for the case of equivalent Hertzian pressure the conformal EHL contact leads to higher lubricant film thickness and lower coefficients of fluid friction and thus in general to advantageous contact conditions.

11:20 **Presentation 07**

Computational lifetime prediction of hydrogen influenced lubricated rolling contact components

Maximilian Baur – Fraunhofer Institute for Mechanics of Materials IWM

In steel bearing elements premature failure due to white etching cracks is a current research topic especially in wind turbine gearboxes. At only 5-10% of the conventional predicted lifetime the damage pattern occurs in the form of brittle flaking. The literature suggests that the accumulation of hydrogen in the subsurface region leads to the observed damage mechanism. To mitigate this effect, it is key to understand the factors affecting this subsurface accumulation. This research work is investigating the major factors affecting hydrogen accumulation and trapping in bearing steel. Preceding work revealed that residual stresses and the dislocation density influences the accumulation of hydrogen in the subsurface region. Measurements of the residual stress and the dislocation density with X-ray diffraction as well as hydrogen content and trapping with thermal desorption spectroscopy on virgin and tested cylindrical thrust roller bearings indicate a modification of hydrogen trapping due to over rolling. The experimental data will be fed into a finite element simulation model whose aim is to study the diffusion of hydrogen and correlate the results of the simulations with full bearing tests to obtain lifetime predictions of bearings suffering premature failure.

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Session “Machine elements and drive technology II”

11:40 **Presentation 08**

Optical analysis of the structural-mechanical effects in the sealing contact of rotary shaft seals

Marco Gohs – Universität Stuttgart

Rotary shaft seals are frequently used in mechanical engineering. However, the lubrication and sealing mechanism is still not understood. A nowadays widely accepted theory is based on the micromechanics in the sealing contact. During mounting, the asperities on the sealing edge surface are pressed onto the shaft. Shear stresses caused by shaft rotation distort the compressed asperities tangentially. The distorted asperities deflect the fluid flow in the axial direction. This creates a back-pumping flow to the fluid side and the rotary shaft seal is leak-tight. This study deals with the measurement of the microscopic, structural-mechanical effects in the sealing contact. A test rig was modified to enable the observation of the contact area through a rotating hollow glass shaft. The sealing characteristics, frictional torque and pumping rate, can be measured simultaneously. The Particle Image Velocimetry was adapted for quantitative measurements of the distortion. The results of the sealing characteristics and the distortions are presented and discussed. By measuring all quantities on the same test rig and under identical conditions, a correlation between the sealing characteristics and the distortions could be established. In summary, this can contribute to a better understanding of the lubrication and sealing mechanism of rotary shaft seals.

12:00 **Presentation 09**

Implementation of an efficient algorithm for simulating the wear of elatstomer rotary shaft seals

Jacqueline Hannss – Universität Stuttgart

Rotary shaft seals are used in many areas of mechanical and vehicle engineering, for example in motors and gearboxes to seal rotating shafts. These sealing systems are tribological systems and often fail due to wear. They therefore often cause a shorter service life of technical products, since the failure of a sealing system usually results in the failure of the entire machine. Due to the complex system behaviour with many influencing factors, the wear of seals can up to now only be analysed experimentally with extremely time-consuming and thus very cost-intensive long-term test runs. A reliable prediction of the service life is thus not possible. Mathematical models for calculating the wear of elastomer rotary shaft seals have been compared. The best models were implemented in FORTRAN as a user subroutine in the MSC MARC MENTAT software. Thus, not only the assembly progress of the sealing ring but also the progress of wear on the sealing

Session "Machine elements and drive technology II"

lip can be determined and simulated. This allows predictions to be made about the functionality of the sealing system and provides insights into the wear progress of rotary shaft seals with elastomer sealing lips.

12:20 **Lunch break**

Session "Lubricants"

13:30 **Presentation 10**

Potential of bio-based lubes investigated with a new rheometer method

Marcella Frauscher – AC2T Research GmbH

Sustainable and safe lubricants used in a wide range of applications, reaching from the automotive industry to devices used for e.g., food production, are essential to accomplish the greening of the European economy. In this work, bio-based friction modifiers (FM) are evaluated via an application-oriented rheometer method and by comparing them with conventional FM. Innovative FM, such as rapeseed and salmon oil, could be a promising alternative for conventionally used FM in lubricants. Finding "green" FM demonstrates a significant step towards developing innovative sustainable technological solutions in lubricant research. In order to have a method, a set of step-by-step instructions leading to an internal standard operating procedure (SOP) was performed to obtain reliable data using the rheometer MCR302. The method was designed under variation of normal force [N], temperature [°C] and sliding speed [m/s]. Resulting from the tests performed in this thesis, the method using a ball (100Cr6) on three plates (1.4301 steel) on the MCR302 was determined to be well suited to compare FMs of different origin.

13:50 **Presentation 11**

Lubricants' shear thinning behaviour – simulations considering additives

Franziska Stief – Fraunhofer IWM MicroTribologie Centrum µTC

Shear thinning, which describes the decrease of a lubricant's viscosity with shearing under the extreme conditions of small gap heights and high pressures, impacts mechanical applications like combustion engines or turbines. For the characterization and the design of new lubricants, molecular dynamics simulations have been proven to be a powerful tool. In this study the shear thinning behavior of the base oil PAO4 containing C30H62 and C40H82 molecules is analyzed and compared for different combinations

of various pressures and temperatures. The lubricant is modeled by an all atom approach and simulated as bulk liquid volume using periodic boundaries. Shear rates in the range of 10^6 1/s to 10^11 1/s are applied and the viscosity is calculated via the shear stress divided by the shear rate. The shear thinning curves are well fitted by the Carreau equation allowing for a quantitative comparison. In addition to this systematic characterization of shear thinning in PAO4, the impact of the additive ZDDP is investigated. The shear thinning of systems containing 0.5 and 5 mass percent of ZDDP molecules will be evaluated for the same parameters as in and compared to the preceding simulations without additives.

14:10 **Presentation 12**

Design of lubricant additives via free energy calculations

Lars Kruse – Fraunhofer IWM MicroTribologie Centrum µTC

Recent trends in Lubricants shift towards lower viscosities. While the lubricant friction is minimized along the Stribeck-curve, the load capacity is reduced as well. To ensure a minimal lubrication gap under load, additives may be added to the base oil, creating a protection layer for the wall surface. To design such additives, information about the ad- or desorption energy is necessary. Over the recent decades, molecular dynamics (MD) simulations became an established method to calculate material properties. Due to the short timescale of MD simulations, external forces are applied, inducing an ad- or desorption of molecules from or to the wall. While this steering simulation is subjected to dissipation, the underlying free energy can be obtained using Jarzinskis equality ⟨exp[-βW]⟩ = exp[-βΔA]. Since the averaging < > requires a vast number of simulation runs, Park and Schulten showed a cumulant expansion approach ΔA=⟨W⟩-β/2 (⟨W^2 ⟩-⟨W⟩^2)+⋯ to greatly reduce the sapling. An applicability of this approach for a free energy analysis and design of additives is tested for a simulation environment consisting of an amorphous carbon wall with a PAO4 base oil.

14:30 **Presentation 13**

Environmentally friendly ester-based lubricating oils for marine propulsion systems

Marius Bürger – RWTH Aachen

Lubricating oils for sterntube bearings are subject to increasingly stringent requirements in terms of their environmental compatibility, as any lubricating oil leakage leads to pollution of the sea. In relation to the container ships used worldwide, this results in an annual discharge of around 80 million liters of mostly mineral oil-based lubricating oils into the oceans, which are already causing catastrophic environmental damage. As a result,

there is a high level of interest in an environmentally compatible lubricating oil alternative. Biodegradable ester lubricants are one possible alternative, whose basic applicability under tribological contact conditions close to the application has not yet been adequately clarified. The aim of the „EcoFEEL“ project is therefore to develop an environmentally compatible ester-based lubricating oil for use in sterntube bearings. In the first step, various model oil formulations will be evaluated with regard to their wear protection capacity and friction efficiency using the Mini-Traction-Machine (MTM). The focus of this initial screening phase is on deriving a suitable test procedure for investigating interactions between different base oil/additive combinations that meet the legal requirements of an environmentally compatible lubricating oil.

14:50 **Presentation 14**

Prediction of engine oil degradation based on FTIR spectra and weighted LASSO regression

Pia Pfeiffer – TU Wien

Recent advances in artificial oil alteration allow for the production of large quantities of degraded oils under laboratory-controlled conditions. To adjust a pre-defined degree of degradation in the laboratory, knowledge of the degradation mechanisms in the field and their connection with the parameters of artificial alteration is indispensable. FTIR spectroscopy is widely used for the analysis of fresh and degraded lubricants. A dataset consisting of 58 FTIR spectra of automotive engine oils in different conditions (fresh, vehicle, artificial alteration) is used to demonstrate an analysis pipeline for FTIR data: First, a procedure based on PCA-reconstruction-error to filter non-informative variables is presented. This preprocessing step does not rely on manual selection of relevant absorption bands, but performs filtering objectively. Then, by means of weighted LASSO regression, a statistical approach and domain experts’ knowledge are combined to derive a quantitative relation between different degradation pathways in engine oils. Eventually, suitable statistical methods to derive confidence intervals based on the concept of post-selection inference are discussed. This leads to models with few variables and high predictive power between duration in artificial large-scale alteration and mileage in a vehicle.

Session “Lubricants”

15:10 **Presentation 15**

Multi-response optimization of machining parameters and halloysite nanotube particle concentration for milling of 4340 steel

Laura Peña-Parás

Many efforts have been done to optimize machining parameters in order to reduce energy consumption and average surface roughness (Ra) of the produced parts. In this study, nanoparticles (NPs) of halloysite clay nanotubes (HNTs) were dispersed into a synthetic lubricant at varying concentrations. A Computer Numerical Control (CNC) milling machine was employed to machine AISI 4340 steel bars with varying input variables of spindle speed (rpm), depth of cut (in), feed rate (in/min), and HNTs concentration (wt.%). A design of experiments based on a three level Box Behnken was performed to obtain the optimum values of input parameters. Spindle load (kW) and Ra of milled steel bars and were recorded after each test. Three models were employed by a Response Surface Method (RSM) to estimate the effect of adding HNTs, to optimize the input variables and to validate the optimized values. The addition of HNTs was found to be statistically significant for Ra and the optimization model showed that the optimum HNT concentration was 0.11-0.17 wt.%. The results obtained with this method show that the optimization of machining processes and HNTs can improve the quality of the produced part and increase productivity.

Session "Lubrication and material engineering"

08:30 **Presentation 16**

Programmable friction: Development of stimuli-responsive tribosystems based on ionic liquid mixtures

Felix Gatti – Fraunhofer Institut für Werkstoffmechanik IWM

The direct but not mechanical control of the frictional properties of bodies moving against each other is one of the major goals in tribology. A suitable combination of lubricant and external trigger represents an enormous challenge. We use ionic liquid mixtures (ILM) consisting of a long-chain cation and different anions to induce a change in friction by an externally applied electrical potential. This change in frictional properties is probably due to changes in the surface charging. This influences molecular adsorption, the exchange of adsorbed ions and their molecular orientation. In addition, a correlation between lubricant film thickness and the quantity of change in the coefficient of friction was found. The coupling of the tribosystem with the electrical potential via a „tribo-controller" enabled a time-dependent autonomous programming of the friction coefficient to predefined valuess.

08:50 **Presentation 17**

Investigation of the tribological behavior of coffee grounds oil as a base oil or additive

Marcela Frauscher – AC2T research GmbH

As the European Union aims for greenhouse gas neutrality by 2050, conventional product cycles need to be reconsidered and the focus is placed on closed value chains. Spent coffee grounds are produced worldwide as a valuable waste resource that can serve as a high-quality feedstock for the production of biodiesel or biolubricant. Coffee grounds oil is analyzed in this study for its physicochemical properties such as viscosity, acid value, water quantity, thermogravimetric analysis and differential scanning calorimetry. Furthermore, the oil is characterized by ATR-FTIR, elemental analysis (CHNSO) and GC-EI-MS. Coffee grounds oil is investigated as a base oil and as a 5% additive in polyalphaolefin (PAO 8) with respect to its tribological properties and compared with PAO 8. Subsequently, the oils are analyzed by Obitrap-ESI-MS and the wear traces are analyzed microscopically. The results show that 100% coffee grounds oil leads to an improvement in friction coefficient compared to PAO 8, with the 5% coffee grounds oil also leading to significant reductions in friction coefficient and wear.

Session "Lubrication and material engineering"

09:10 **Presentation 18**

Self-lubrication at high temperatures— Role of sulfides

Rahul Kumar – Tallinn University of Technology

The accelerating advancements in the field of hot-tribology has led to an integral research on environmentalyl friendly steps. Negative impact (or toxicity) of conventional liquid based lubricants (petroleum-origin) to environment (non-biodegradable) as well as to the operator (as toxic fumes, causes cancer, respiratory illness) is widely reported. Self-lubricating materials are a group of materials utilizing the benefit of solid lubricating compounds (such as, PTFE, hBN, CaF2, MoS2, graphite, etc.) to minimize friction and wear. In spite of a constant considerable reporting work in the field, there exist a major focus to widen the working temperature range of such materials by incorporation of a high-temperature solid lubricants (either ex-situ or in-situ formation). Lubrication by in-situ sulfide formation is a fairly new topic (such as, Chromium sulfide), leading to a lack of dedicated study in the field. The present work fills the gap and demonstrates the microstructural and tribological influence of NiS, CuS and BiS on high temperature self-lubrication behavior of Ni-based laser claddings. The tribological tests were made from room temperature to 600 °C. The characteristic features of wear mechanisms are presented and discussion is supported by advanced characterization techniques.

09:30 **Presentation 19**

Crystal rotation kinematics during early-stage sliding uncovered by electron backscatter diffraction

Christian Haug – Karlsruher Institut für Technologie (KIT)

Tribological loading of metallic materials leads to pronounced microstructural modification, often by dislocation-mediated plastic deformation. Since Bowden and Tabor's seminal work, it is well known that the mechanical properties of materials in contact influence tribological properties such as friction and wear. In this context, the local orientation of the crystal lattice in contact constitutes an important influence on plastic deformation behavior, especially on the microscale. During continued sliding, the development of crystallographic textures is often observed, which requires a reorientation of the crystal lattice, or crystal rotation. This fundamental process is not yet sufficiently understood. The present work thus presents a detailed analysis of the early-stage crystal rotation kinematics induced by a single dry sliding pass of sapphire spheres on a high-purity copper bicrystal. Electron backscatter diffraction (EBSD) performed directly on the bulk surface of the wear tracks reveals that crystal rotations around the transverse direction (TD) are at the heart of crystal rotation kinematics, irrespective of grain normal orientation, sliding direction and load. Three

distinct crystal rotation processes are identified and quantitatively analyzed. These insights into the fundamental mechanisms involved in early-stage microstructure evolution provide an important lever for tailoring materials and systems towards beneficial tribological properties.

09:50 **Presentation 20**

Effects of different load collectives on high temperature wear behaviours

Tobias Rosenstingl – Fraunhofer Institute for Mechanics of Materials IWM

In the field of high temperature tribology, where degradation and evaporation prevent lubrication with liquids, classical wear mechanisms determine the tribological behaviours. Besides abrasion and adhesion, oxidation plays an important role with rising temperatures and enables a wear reducing tribolayer formation, a favourable tribological behaviour. At first bare material surfaces and debris must oxidise and then temperatures and contact pressures trigger sinter processes that lead to the layer formation. This complex interaction is strongly depending on the applied load collective, like temperature, sliding speed, normal force and on the material composition. This contribution shows the results of different load collectives on the wear behaviours of selected material pairings. The tribological tests were carried out on a reciprocating sliding test stand with a line contact geometry. The tribological surfaces were characterised by confocal, light and electron microscopy and metallographic sections provide insights into the layer structure. The experimental results indicate a tribological beneficial layer formation in the case of cast iron against chromium plating from temperatures of 600°C. Comparative results with a pairing of cast iron against heat resistant steel at the same conditions show higher wear and no tribolayer formation.

10:10 **Presentation 21**

Tribological performance of as-cast and aged $AlCoCrFeNi_{2.1}$ E-HEA

Fevzi Kafexhiu – V-Research GmbH

In the present study, wear behavior as a function of aging time was evaluated for the $AlCoCrFeNi_{2.1}$ eutectic high-entropy alloy (EHEA), which at the as-cast state consists of B2 (BCC) and L12 (FCC) phases in lamellar morphology. By aging the material up to 500 h at 800 °C, precipitation of a fine, evenly dispersed micro-phase inside the L12 takes place. From 500 h to 1000 h of aging, precipitates coarsen by the Ostwald ripening mechanism. Reciprocating wear tests performed on both as-cast and aged material were characterized by prevailing abrasive wear, while adhesive and delamination wear components changed with aging conditions. The L12 phase with lower hardness in the as-cast state preferentially deformed during

the wear test, which was not the case after aging the material, i.e., with the presence of precipitates. Aging-induced changes show a similar trend for the coefficient of friction and L12 + precipitates phase fraction, whereas changes in specific wear rate are in good agreement with changes in the B2 phase fraction. In general, aging the $AlCoCrFeNi_{2.1}$ EHEA at 800 °C up to 500 h decreases its coefficient of friction due to reduced adhesive wear component and enhances its wear performance through precipitation strengthening.

10:30 **Presentation 22**

Development of sensor inserts on non-planar substrates for Temperature measurements during ball on disc testing

Selina Raumel – Leibniz University Hannover

Oxide layers on metal surfaces adversely affect the processability and material properties in many industrial applications. This research work shows the study of the correlations between oxide film thickness and the changes in mechanical properties. For the studies, a precise surface pressure without relative motion was applied by nanoindentation measurements on 99.9999 % pure plasma-assisted deoxidized copper samples and samples covered with sputtered ultrathin oxide layers of different thicknesses. The results showed a significantly stronger wear behavior and a reduction in the mechanical properties on the samples with different oxide layer thicknesses compared to the deoxidized samples. Furthermore, a dependence between the forces necessary to reach plastic flow and the oxide layer thickness could be identified.

10:50 **Break**

Session "Coatings and surface technologies"

11:20 **Presentation 23**

Dry Sliding Tribological Properties of a Polymer Coating System

Laura Guetse Dongmo – ELB-Eloxalwerk Ludwigsburg Helmut Zerrer GmbH

The applications of aluminum and its alloys are still limited by low corrosion and low wear resistance properties. Surface modifications, such as surface coating, represent a feasible way to overcome these drawbacks. In this study the development of a multilayer approach is presented, where PEEK (poly-ether-ether-ketone) is used as a base coating material for Aluminum substrates. The aim of this study is to create a polymer coating system, which is composed of a first layer against corrosion, followed by a tribological layer for wear protection and a final running-in top layer with solid lubrication behavior, whereas each layer is applied by using photonics. Through a comparative study of various additives in the PEEK dispersions and their variable concentrations, a multilayer system was established. The polymer coating systems were subjected to bidirectional linear dry sliding wear tests, using a steel ball as a counter body. Surface and structure characterization of the samples was performed before and after the tribological tests, using a wide range of techniques. The wear scars were characterized by Laser Scanning Microscopy, Digital Microscopy and Scanning Electron Microscopy. The results show that a multilayer system has the ability to increase the corrosion and wear resistance properties of aluminum, thereby increasing the lifetime of the components.

11:50 **Presentation 24**

Running-In of DLC and its nanoscale footprint

Joachim Faller – Fraunhofer IWM

In this study the Running-In behavior of a ta-C coating paired with an iron spray coating lubricated with a fully formulated engine oil was observed in a pin-on-disk tribometer coupled with high resolution wear measurement (RNT). Running-In of the tribosystem was achieved with the method explained in. Topographical Running-In of the DLC was measured via AFM. Changes in (sub-)surface chemistry were analyzed with XPS depth profiling and for the iron coating FIB and REM were used to reveal subsurface microstructure. As expected, Running-In of the iron coating was influenced by Third Body formation linked to mechanochemistry and decreasing grain size on the first 100nm, which lead to wear rates in the vicinity of 2 to 5 nm/h. The DLC however, exhibited ultra low wear rates (below 0.1 nm/h) after topographical Running-In. XPS depth profiling showed a chemical change on the first 15 nm of the ta-C. This appeared to be sulfur doping and a significant increase in sp2 content below the surface. In summary the Running-In of DLC displayed a similar mechanism like an iron coating but left its traces on a much smaller scale.

Session “Coatings and surface technologies”

12:10 **Presentation 25**

Tribological comparison of different doped DLC

Markus Polzer – FAU Erlangen

Diamond-like carbon (DLC) coatings are widely used as low-friction, wear-resistant functional layers on mechanically stressed components. Especially the automotive industry anticipates a benefit in applying such coatings in gear and engine components, resulting in a complex tribological system. For newly developed coatings the lifetime and general efficiency of the resulting tribosystem can just be assumed but not be predicted solely by considering the doping elements and the mechanical properties of the coatings. The BWMi project PROMETHEUS aims for a better understanding of the influence of different doping elements in a lubricated tribocontact, which is examined within the scope of this contribution. For this purpose, various doped DLC coating systems have been developed, deposited and compared to an undoped, hydrogenfree ta-C coating and uncoated samples. The tests with coated samples are conducted on a ball-on-disk-tribometer and in an Optimol two-disk test rig under mixed/boundary conditions. For lubrication, a commercially standardized additive-free Oil and a Mo- and Zn-containing oil are used. Different factors such as influences of the lubrication, surface chemistry and wear behaviour are investigated and the aim is to illustrate and compare the effects of the doping elements on the friction and wear behavior.

12:30 **Lunch Break**

Session "Biotribology and life sciences"

13:30 **Presentation 26**

Biotribological screening of amorphous carbon coatings on hard-on-soft pairings for total knee arthroplasty

Kevin Neusser – FAU Erlangen

The purpose of endoprosthetic joint replacement is to regain the functionality and allow patients to live a more mobile and pain-free life. Aseptic loosening of total knee arthroplasty (TKA) is a major cause of premature failure, with wear particles removed from the implant materials being largely responsible. Therefore, great efforts are being made to reduce the wear of polymer inlays by surface modifications. This study concentrates on the screening of the effectiveness of wear-reducing amorphous carbon coating systems on hard-on-soft pairings (metal-on-polymer). The biotribological behavior of the uncoated and coated pairings is investigated using a climate- and stress-controlled rheometer supplemented with a tribo-cell in a polyethylene ball and three metallic pins configuration, lubricated with diluted bovine calf serum (BCS) at 37 °C, in oscillatory sliding mode. The frictional behavior is analyzed in-situ while the wear performance is characterized ex-situ using light microscopy and laser scanning microscopy. This screening reveals the applicability of amorphous carbon coatings to the considered materials used for biomedical applications. It demonstrates the potential for wear reduction and forms a basis to determine the most promising of the deposited diamond-like carbon (DLC) coatings, therefore allowing for more focused research in the development of tribologically effective coating systems.

13:50 **Presentation 27**

Biotribological behavior of MXene-UHMWPE-composites for total knee arthroplasty

Klara Feile – FAU Erlangen

MXenes are a relatively new class of two-dimensional transition metal carbides, nitrides and carbonitrides experiencing increasing attention for tribological applications. Due to their multi-layer structure with relatively weak inter-layer bonding, a self-lubricating character is enabled. A possible, but not yet explored, application of MXenes is the addition to UHMWPE with the aim to improve the biotribological behavior of tibial inlays of total knee arthroplasties (TKA). Within this study, $Ti_3C_2T_x$-UHMWPE-composites with 0.5 wt.-%, 1.0 wt.-% and 2.0 wt.-% MXenes were biotribologically tested using a pin-on-disk tribometer in oscillating sliding mode lubricated with diluted bovine calf serum at 37 °C. Thereby, a reduction of the coefficient of friction by up to 22 % compared to pure UHMWPE was demonstrated and the determined wear rates of the disks decreased considerably by 25 % (0.5 wt.-% and 1.0 wt.-%) and 43 % (2.0 wt.-%). Furthermore, the

composite-disks reduced the wear rates of the tested Co28Cr6Mo-pins by up to 19 %. Both the reduction of friction and wear show the great potential of MXenes as a reinforcement phase to UHMWPE to improve the biotribological behavior of tibial inlays and thus, increase the long-term service life of TKA.

14:10 **Presentation 28**

Tribological behavior of ceramic disks for application in mixer taps under different lubrication conditions

Marlene Ziegler – FAU Erlangen

Technical ceramics are used in many tribo-technical applications due to their chemical inertness, high hardness, and wear resistance. As such, two ceramic disks are integrated in the mixer cartridges of water taps. A common problem is the change of haptic response during usage because of changes in the tribological system. Within the scope of this contribution, the possibility of reproducing effects relevant for the application using fundamental model tests is studied. Thereby, three mixer taps with different haptic properties were used as references and ball-on-disk experiments in reciprocating sliding mode at room temperature were used to test the ceramic-ceramic-pairings under dry and grease-lubricated conditions. The addition of grease led to a considerable friction reduction compared to testing under dry conditions. The wear behavior was also influenced by the lubrication conditions. Further tests at a temperature of 65 °C to simulate hot water inflow revealed that there was no considerable influence on friction for dry conditions compared to testing room temperature while the tribological behavior was affected for the lubricated tests.

14:30 **Presentation 29**

Bio-Tribology: How does the use of sustainable bamboo toothbrushes influence our everyday life?

Matthias Reiser – Optimol Instruments Prüftechnik GmbH

In „Tribology in 2022 - contribution to sustainability and everyday life“ tribological parameters between tooth, toothpaste and toothbrush were investigated in category V laboratory tests. The real-world system tooth-toothpaste-toothbrush was systematically transferred to a laboratory scale, which was implemented to tribometer test rigs. During the abstraction of the real-world system as many components of the original tribosystem as possible were retained. In addition the abstraction was selected so that the method could be transferred to other test rigs. For the evaluation of the test subjects an optical measurement method was developed to investigate the wear mechanisms at the end of each test run. Based on eight test series and a total of 200+ h test duration it was shown, that it is pos-

sible to differentiate between the tribological partners tooth, toothpaste and toothbrush. With the help of these measurement method it is now possible to recommend the use of sustainable oral hygiene products with a view to gentle cleaning for everyone in everyday life. Based on scientific investigations. First results showed e.g. that the negative effects of an aggressive brushing technique can not be compensated by particularly gentle toothbrushes and toothpastes. Besides that, also bamboo toothbrushes got investigated.

Additional Information

Registration

If possible, please register until 1st June 2022
The registration form can be found on the Young Tribologists website:
https://junge-tribologen.de/en/registration-en/

Registration fees 2022:

Regular participants	50 €
Speakers	25 €
Enrolled students (until Master / Diploma)	25 €

Cancelation policy

Free of charge cancellation (in writing) is possible until 1st June 2022. It is possible to send an alternate delegate. No refunds will be given for cancellations after 1st June or for no-shows.

Information

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