Junge Tribologen

GfT Gesellschaft für Tribologie e.V.

6th Young Tribological Researcher Symposium

YTRS

24th – 25th of July 2023

at University of Bayreuth

Patron:

S. Tremmel

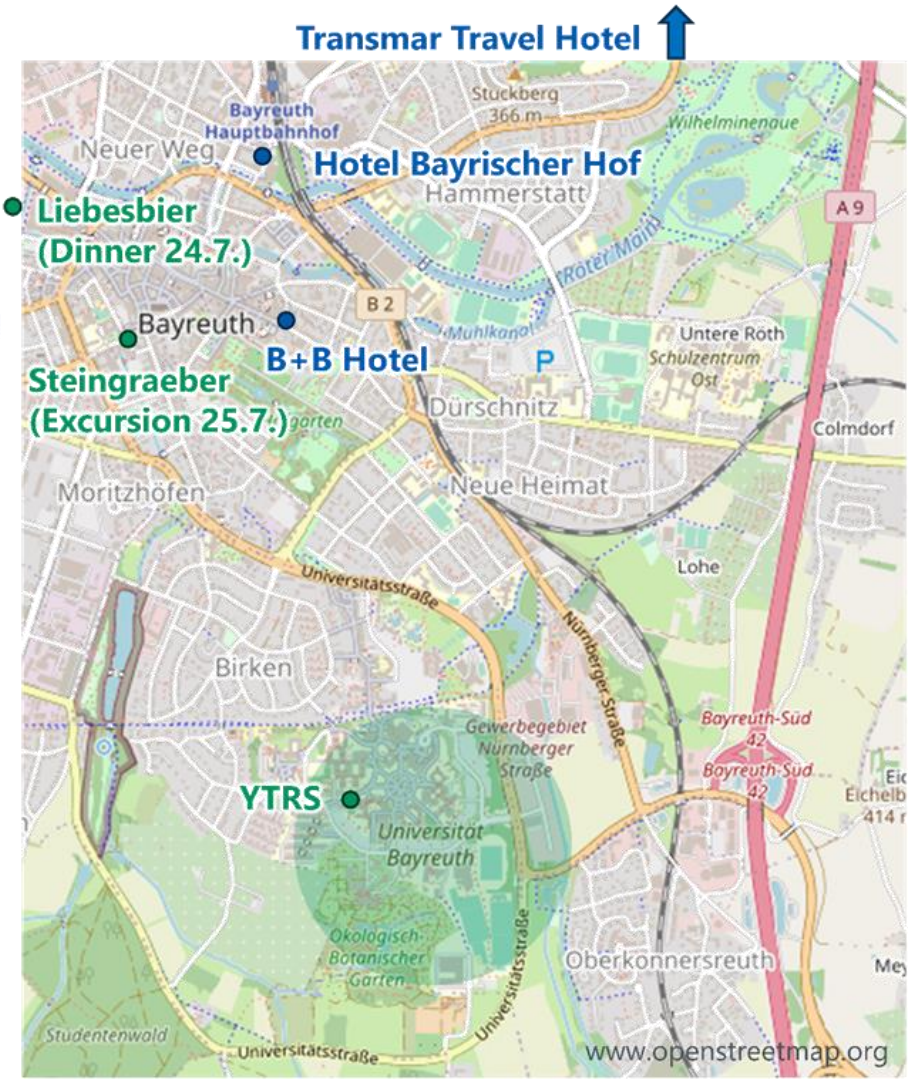
Program and organization:

M. Marian
C. Morstein
C. Orgeldinger
B. Rothammer
F. Rummel

Content

Location

University of Bayreuth
Engineering Design and CAD
Universitätsstraße 30
95447 Bayreuth
Germany



The university campus is located on the southern outskirts of the city. Approx. 900 meters away from the junction "Bayreuth-Süd" (AS 42) of the freeway A 9.

By car: Leave the A 9 freeway (Nuremberg - Berlin) at the "Bayreuth-Süd" exit in the direction of the city center. Follow the signs to "Universität". After the main entrance keep left and follow the road until the buildings of the Faculty of Engineering Science appear on the left side.

Arrival by train: At Bayreuth main station you will find cab stands and bus stops on the forecourt. Bus line 316 (limited trips) shuttles between the main station and the campus or take another bus line to the Central Bus Stop (ZOH) and take bus lines 304 (Birken/Universität), 306 (Universität/Campus) or 326 (Oberfrankenhalle/Campus) to the "Geowissenschaften" stop.

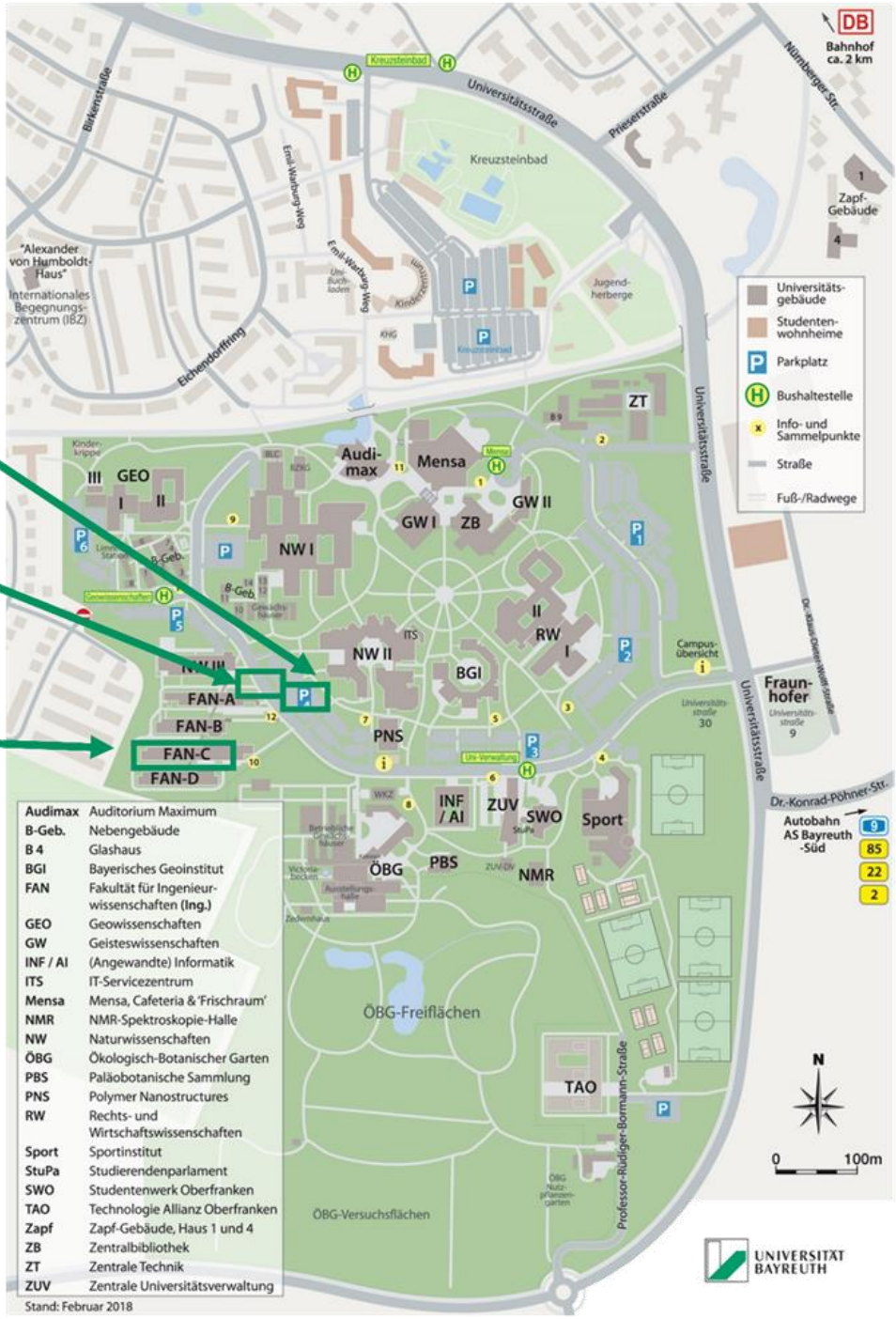
Arrival by public transport: There are three stops "Mensa, Geowissenschaften, Uni-Verwaltung" distributed on the campus. Line 316 (limited trips) shuttles between the main train station and the campus. You can also reach the campus via the Central Bus Stop (ZOH) with lines 304, 306 or 326. To get to the buildings of the Faculty of Engineering Science, it is best to use the stop "Geowissenschaften".

Lehrstuhl für Konstruktionslehre und CAD
Prof. Dr.-Ing. Stephan Tremmel

Parking

Bus stop

YTRS - Symposium



Dinner and Excursion:

On Monday evening, we will go to dinner at "Liebesbier" together by public transport. Alternatively, it is also possible to go by car and/or to do the hotel check-in between the symposium and the evening event.

On Tuesday, we will go to the piano manufacturer "Steingraeber & Söhne" in the city center together by public transport and/or organized in cars. From there on, after the excursion, the train station is within walking distance.

Program overview

Monday, 24th July 2023

11:00 – 11:45	**Opening and welcome** M. Marian, C. Orgeldinger, B. Rothammer *Working group "Young Tribologists", GfT* S. Tremmel *Engineering Design and CAD, University of Bayreuth*
11:45 – 12:30	***Institute tour***
12:30 – 13:30	***Lunch break***
13:30 – 14:30	**Presentation session "Tribo-materials"**
14:30 – 15:00	***Coffee break***
15:00 – 16:30	**Presentation session "Machine elements and drive technology"**
From 19:00	***Get together and dinner*** *Liebesbier – Hotel, Restaurant & Bar, Andreas-Maisel-Weg 1, Bayreuth*

Tuesday, 25th July 2023

09:00 – 10:30	**Presentation session "Tribo-testing and data processing"**
10:30 – 11:00	***Coffee break***
11:00 – 12:00	**Presentation session "Biotribology"**
12:00 – 13:00	***Lunch break***
13:00 – 13:30	**Best presentation award and symposium closing** M. Marian, C. Orgeldinger, B. Rothammer
14:30 – 16:00	**Excursion** Steingraeber & Söhne, Dammwäldchen 1, Bayreuth

Presentations

Monday, 24th July 2023

Session "Tribo-Materials"

Session Chair: M. Marian, Pontificia Universidad Católica de Chile, Chile

13:30 **Presentation 01**

Evaluating the tribological behavior of nitrogen-modified MoS_2 coatings under vacuum conditions

Armin Seynstahl, University of Bayreuth, Germany

Molybdenum disulfide (MoS_2) is frequently used as solid lubricant operating in challenging environments, e.g. in vacuum. This work evaluates the compaction occurring during the initial contact stage of pure and nitrogen-modified MoS_2-coatings in vacuum. Tests of cylindrical PVD-coated 100Cr6 steel discs paired with spherical 100Cr6 steel discs were conducted on a two-disc-tribometer. The Slide-Roll-Ratio (SRR) of 10.5 % was kept constant, while the load was varied in two steps. Subsequently, a comparison was made between the worn and pristine coatings by means of mechanical and optical analysis of the wear track. The formation of a load-bearing solid lubrication, while compacting the coating, was achieved for both MoS_2 variants. The compaction mechanism was independent of nitrogen-modification, but scaled with increasing load. The compacted coatings reached a similar level of density, indicated through an increased hardness, suggesting an independency of the initial coating properties. Overall, the frictional behavior was equally independent of the coating or the applied load. The main differences affected material transfer and wear mechanisms. The MoS_2:N coating showed both, wear until the substrate surface in the middle of the wear track and less compaction than pure MoS_2, while maintaining an almost identical level of mechanical properties and frictional behavior.

Cancelled **Presentation 02**

Static Friction of Superlubricious 2D Systems

Ahmed Uluca, Trinity College Dublin, Ireland

In this presentation, I will talk about ultra-low friction found at a single micro-scale asperity facilitated by structural superlubricity of 2D materials. Our sheared oscillatory experiments created a Mindlin-style contact which has gained importance for revealing macroscopic friction behavior of interfaces. The Mindlin picture of the contacts clarifies the transition between fully stick to gross slip that determines the static friction coefficient. Here, we demonstrate this transition for single micro-asperity with a depth resolved 2D indentation experimental design on superlubricity expected 2D materials. Detailed analysis of small-amplitude oscillatory Mindlin-Hertz contact has been conducted to extract shear strength, from which a static friction coefficient can be extracted with well-defined single micro-contact geometry. Moreover, we suggest how to extend this study to conceptual meaning of stick regime and static friction for super lubricity.

14:00 **Presentation 03**

Per Aspera ad Astra – Friction reduction with star polymers

Lars Kruse, Fraunhofer IWM - MikroTribologie Centrum, Germany

Towards more energy-efficient vehicles, machines and industrial plants, the reduction of friction losses in tribological systems can make a further, important contribution. From the lubricants point of view, this optimization is driven primarily by three factors: Lower viscosity, use of unconventional base oils and friction-reducing additives. In this context, fundamental conflicts of objectives have to be solved. The trend towards ever thinner lubricating oils, leads - keeping other conditions unchanged - to a lower lubricant film thickness, associated with the risk of greater wear. This can be addressed by using low-friction, wear-resistant component coatings - or by using film-forming polymers in the lubricant. However, this raises a new problem: Conventional polymer additives for lubricants, e.g. the well-known viscosity index improvers (VII), lead to thickening of the base oils. As a consequence, the base oils would have to be significantly "thinner" again, which in turn is limited for reasons of significantly increasing evaporation losses. A promising approach has been explored in the BMWK project PROMETHEUS in a joint effort of atomistic simulation (Fraunhofer IWM-MikroTribologie Centrum), controlled polymer synthesis (Fraunhofer LBF), and tribological experiments (FUCHS LUBRICANTS): Star polymers that do not noticeably thicken the lubricating oil, but are interfacially active.

Session "Machine elements and drive technology"

Session Chair: B. Rothammer, FAU Erlangen-Nuremberg, Germany

15:00 **Presentation 04**

Lubricating Conditions in Greased, Oscillating Rolling Element Bearings

Gernot Bayer, Leibniz University Hannover, Germany

Oscillating, rolling element bearings, such as blade bearings in wind turbines, can experience wear due to their unconventional movement. Previous investigations on ball bearings already clarified the influence of oscillation frequency and angle as well as grease properties. Revaluation with respect to the entrainment speed shows a grease characteristic threshold for wear initiation. This work further assesses the greases previously tested by optical investigations on a tribometer. The setup allows observing the grease distribution around the contact, which exhibits a meniscus-like shape, known from oil-lubrication. A central parameter is the inlet length that is directly proportional to the amount of grease in front of the contact. Observation of the inlet length under increasing frequency shows a continuous decrease. The critical speeds of the bearing tests correlate with the speeds at which the meniscus has fully retracted in front of the contact. Analysis reveals that the inlet length is depended on the capillary-number; hence, it follows the same underlying physical mechanism already known from oil. In addition, the bleeding rate of the oil has a significant effect. The presented results may help to improve the understanding of the lubrication mechanisms in greased oscillating bearings and to predict the onset of wear.

15:30 **Presentation 05**

Analysis of technical influence factors on the radial shaft seal test

Yongzhen Lin, TU Bergakademie Freiberg, Germany

This work deals with a methodically representable interpretation among repetitive investigations focusing on the technical influence factors on the radial shaft seal (RSS) test. Previous research findings have shown that the tribological behaviors collected from repetitive investigations are eventually recognizable and classifiable after processing with a huge amount of raw data. In this work, the focus is to understand the different technical influence factors of the repetitive investigations, in other to reduce the amount of repetitive investigations. Generally, a new investigation has to be repeated for more than 3 times to ensure that the results are reproducible and representative. The process is undertaken with a high expenditure of time, energy, and resources. In this work, test results will be analyzed statistically such as friction coefficient distribution during measurement irregularities, range and classification of these irregularities. The experimental examinations pay particular attention to different boundary conditions such as with or without assembly process. An RSS test rig specifically designed at the IMKF institute is available for the experimental investigations. The purpose of this analysis is to create a basis for future research into optimizing options for RSS test as well as prediction of specific investigations for different RSS systems.

16:00 **Presentation 06**

Thermal Elastohydrodynamic Analysis of a Worm Gear

Marko Tosic, TU Munich, Germany

This study explores the elastohydrodynamic lubrication (EHL) between the contacting tooth flanks of a worm gear with non-conjugate meshing action. The contact is characterized by a slender like elliptical shape and high sliding. The geometry and contact conditions for the considered worm gear were obtained using tooth contact analysis. Based on that, the complete area of the worm gear contact was analyzed using a validated numerical EHL model considering non Newtonian, thermal, and transient effects. The geometrical and kinematic design factors that influence EHL film formation in worm gears were identified and discussed. The results show the specific characteristics of worm gear EHL contacts, such as the very slender contact in the tooth root flank area, which diminishes the effect of the entrainment speed on film thickness. EHL film formation could be supported by increasing conformity between the flanks to make the contact less slender. By comparing the film thickness results against analytically obtained ones, relatively large differences were observed except for one formula for minimum film thickness.

Tuesday, 25th July 2023

Session "Tribo-testing and data processing"

Session Chair: C. Orgeldinger, University of Bayreuth, Germany

9:00 **Presentation 07**

Evaluation of static, kinematic, and integral CoF from variable-frequency reciprocating sliding tests

Fevzi Kafexhiu, V-Research GmbH, Austria

Reciprocating sliding friction tests are characterized by two contacting bodies performing linear oscillating motion relative to each other at a chosen contact pressure, oscillation frequency, and amplitude. At maximum amplitude positions, the sliding velocity is zero and the relative motion of contacting bodies is reversed. Immediately after, the friction signal is usually characterized by a peak, representing the static coefficient of friction (CoF), followed by the sliding part usually characterized by a plateau, representing the sliding (kinematic) CoF. To be able to accurately reveal the static CoF and accurately calculate the kinematic and integral CoF from the friction signal, a sufficient density of data points per unit time is required. Since some tests are performed at a variable oscillating frequency, for a constant data acquisition rate, the density of data points per unit time also changes, making the evaluation process more challenging. In addition, a low signal-to-noise ratio poses another challenge in the evaluation process because of multiple alternating CoF peaks appearing in the sliding part, which can be higher than the usual peak of the static CoF. These and related challenges together with the methods utilized to efficiently overcome them will be addressed in the present work.

9:30 **Presentation 08**

Calculating the electrical contact capacitance in elastohydrodynamic lubrication conditions

Stephan Puchtler, TU Darmstadt, Germany

The electrical properties of tribological contacts become increasingly important. On the one hand, there is interest in the influence the contacts exert on the electrical system behavior, and on the other hand, there is a demand for installation-space neutral in-situ sensors, which can be achieved by measuring the operating condition dependent electrical properties. This work focuses on hydrodynamic and elasto-hydrodynamic lubrication conditions, where the contact capacitance is usually the most relevant electrical property. Analytic, semi-analytic, and numeric calculation methods are compared, advantages and limitations discussed, and recommendations given, following the example of a rolling bearing's ball-on-race contact. Characterizing capacitance comes with various challenges: It is time-variant and depends on the operating conditions as well as the lubricant properties, which in turn are a function of temperature and pressure, to name a few. Furthermore, an adequate understanding of the contact geometry is key. In the case of an elasto-hydrodynamic contact, the load-carrying Hertz'ian area is central to the electrical behavior, but the surrounding area is usually not negligible either and needs to be addressed with the calculation methods mentioned above. Furthermore, an outlook on mixed lubrication conditions as well as contact resistance calculations is given.

10:00 **Presentation 09**

Condition Monitoring in journal bearings using the intrinsic electric properties

Florian Kötz, TU Darmstadt, Germany

The utilization of sensor data is becoming increasingly more important for condition monitoring in order to optimize maintenance cycles. The aim is to be as close as possible to the point of interest to provide the highest data quality with the least amount of disturbance. One promising solution is to utilize the electrical properties of machine elements as sensors. This has already been demonstrated for roller bearings but similar research in regard to journal bearings is limited. Journal bearings form a lubrication film when operated in hydrodynamic lubrication that is dependent on load, rotation rate, temperature, the physical properties of the lubricant and the geometry of the journal bearing. The lubrication film causes a capacitive electric behaviour that can be measured in an AC-circuit with the aim to derive operating conditions from the measurement. At the author's institute, a simulation of the electric behaviour of a journal bearing test bench is developed and compared to test bench results. The aim is to show the potential and current limitations of condition monitoring using the capacitive behaviour of journal bearings and to investigate whether individual operating conditions can be derived from the electric behaviour.

Session "Biotribology"

Session Chair: F. Rummel, Netzsch-Gerätebau GmbH, Germany

11:00 **Presentation 10**

Evaluation of the Microstructure and Tribological Properties of the Micro-arc Oxidised Biomedical Titanium

Faiz Muhaffel, Istanbul Technical University, Turkey

In the biomedical industry, titanium and its alloys are attractive materials since they exhibit low density, low Young's modulus, high tensile strength, and good biocompatibility. However, their poor wear resistance and ease of surface degradation limit their widespread use. For example, the poor wear resistance of titanium and its alloys causes aseptic loosening after implantation and inflammation of the surrounding tissues, which can result in bone resorption (osteolysis) as wear debris enters the bloodstream. Osteolysis can lead to implant failure and must be prevented to maintain the long-term success of the implant. Therefore, the surface modification of titanium-based implants is necessary to extend implantation periods by minimising in vivo surface degradation under mechanical loading. Micro-arc oxidation is an electrochemical surface treatment that has emerged as a promising method for combining wear resistance with bioactivity, enhancing both the tribological and biological properties of implants. An innovative multilayer coating consisting of a bioactive outer layer over a titanium oxide-based inner layer was developed in the present study. Following the microstructural characterisation of the samples, tribology tests were conducted in an artificial environment imitating the conditions found in body fluids.

This work was supported by the Scientific Research Projects Department of Istanbul Technical University, Project Number: MGA-2021-43412.

11:30 **Presentation 11**

Amorphous carbon coatings for total knee arthroplasty – A knee simulator evaluation

Kevin Neusser, FAU Erlangen-Nuremberg, Germany

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 evaluation 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 TKA is investigated in a knee simulator according to ISO 14243. The articulation is lubricated with diluted bovine calf serum (BCS) at 37 °C mimicking in vivo boundary conditions and motion parameters. The wear is quantified by gravimetry after a total of 3.5 million cycles and the gravimetric wear of the polymeric tibial inlays are calculated in intervals of 500,000 cycles. This testing reveals the applicability of amorphous carbon (also known as diamond-like carbon (DLC)) coatings to the considered materials used for biomedical applications. The results represent an important milestone in demonstrating the potential of DLC coated contact partners for wear reduction in human joints.

Contact information

Junge Tribologen
Gesellschaft für Tribologie e.V.
Adolf-Fischer-Str. 34
D-52428 Jülich
E-Mail: tribologie@gft-ev.de, info@junge-tribologen.de
Internet: http://www.gft-ev.de, https://junge-tribologen.de/

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