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UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Titre de la thèse/Thesis title : NanoMechanics of Materials for Tribology

Laboratoire d'accueil / Host Laboratory : Institut FEMTO-ST / département MN2S

Spécialité du doctorat préparé/Speciality : engineering sciences, nanocharacterization, tribology

Mots-clefs / Keywords : Nanomechanics, tribology, material sciences

Descriptif détaillé de la thèse / Job description

Introduction / context:

Developing new solutions to solve energy and environmental problems must include tribology. Although significant research has been carried out in tribology, with a large number of new lubricants (coatings, oils, greases), the negative impact of friction and wear on the economy and the environment remains significant, and efforts are still needed [1,2]. However, the challenge of tribology is that a complete understanding of the processes governing tribological behavior and wear life, in order to predict them, requires an understanding of the existing synergy between mechanics, physical chemistry and thermodynamics within the contact [3]. The greatest challenge is "the complexity of direct measurements and the inseparability of various multiphysical mechanisms in real interfaces" [4] that must be considered. This is particularly true of the tribology of dry-lubricated contacts, whose configuration (properties of the surfaces in contact, and the nature of the interface) is constantly evolving. Whatever the purity of the materials making up dry lubricants, once exposed to air they come into contact with ubiquitous contaminants. Some recent studies have unexpectedly shown that low wear may be the result of a complex physico-chemical competition between the materials in contact, their internal contaminants (in volume and surface) and external contaminants (from the gaseous environment), to create lubricating interfaces through mechanically activated chemical reactions [5–10]. These reactions have led to the self-elaboration of multiphase lubricating and/or anti-wear composite materials (which we call 3rd bodies), within the contact itself.

The mechanical properties of this 3rd body are very important, as they affect the friction response, and therefore the level of friction and its stability. It is essential to develop strategies for accessing the mechanical properties of the interfacial materials created during friction, and also of the wear particles (3rd body ejected from the contact). The highly "chaotic" environment of a friction track does not allow the use of traditional approaches [11,12] in large number of cases. Indeed, surfaces can be rough (a few tens to a few hundreds of nanometers) for low material thicknesses, or in the form of "patches" not necessarily chemically bonded to the substrate, with local topographic elevations, and so on. The strategies commonly encountered in the literature remain "conventional" and mainly use nanoindentation (ex-situ and in-situ) and micro/nano-pillar compression, without being certain of satisfying all the appropriate conditions for these techniques. [11]. We recently developed [13] an approach based on controlled gripping of wear particles. The particles are sampled directly in the vicinity of the contact with an instrumented micro-gripper, and compression tests are carried out to determine stresses and strains. However, the data obtained require further study. Versatile and functional for particles, it is not as effective for 3rd bodies in the form of long thin layers. To this end, we are proposing to complement our micro-comprehension by developing an approach for measuring mechanical properties using atomic force microscopy (AFM), and in particular by using the PeakForce QNM High Accuracy mode, available since this year at the FEMTO-ST institute. The aim is to develop a strategy and a method for characterizing tribological materials, providing access to elastic, plastic, and adhesion properties of the different materials presents inside the contact interface. These data will be used to feed numerical models developed in parallel through collaborations, such as discrete element models, notably for MoS2-based lubricant thin deposition. [14].

Proposed work:

The thesis will be carried out in the MN2S department of FEMTO-ST Institute (Besançon, France, https://www.femto-st.fr/en/Research-departments/MN2S/Presentation). The work envisaged will focus on analyzing the mechanical properties of 3rd bodies generated in a dry lubricated contact by a thin coating (MoS2) that underwent friction in various environments (vacuum, air, contaminated air). We have extensive experience with MoS2 [5,14–18]. The SnO2 material, whose deposition we have mastered [19], is a very interesting case study, as it is sensitive to very specific contaminants which have a significant impact on its tribological performance (friction and wear). SnO2 can therefore be used as a benchmark material to validate the approach. The application case will remain MoS2. The aim is to develop small-scale analysis methods linking the mechanical properties of the 3rd bodies to their physicochemical and microstructural nature, and to their friction/wear behavior.

The objectives are :

1- Develop a generic method for the characterization and mechanical analysis of 3rd bodies at nanometric scales using AFM and controlled in-situ sampling/characterization. We are currently pioneering in-situ approaches with localized sampling. As the sampling is functional, the student will mainly interact with the AS2M department at FEMTO-ST to use the existing device.
2- Establish a first quantitative link between the mechanical properties of the 3rd bodies, their chemical nature (linked to the test environment), and the coefficient of friction. Coupling, using a well-proven investigation method, with surface analysis by Scanning Electron Microscopy (SEM), and chemical analysis of the environment (mass spectrometry during testing) and surfaces (XPS, Raman) will be used to complement the mechanical measurements.

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Tribol. Int. 163 (2021) 107194. https://doi.org/10.1016/j.triboint.2021.107194.

Profil demandé / Applicant profile

Master 2 (or Engineering equivalent) in mechanics, materials sciences, surface sciences, physics of solid

Preferred selection criteria:
- Knowledge of surface and materials characterization (physical chemistry, topography, microstructure, and mechanics)
- Knowledge of atomic force microscopy
- Experience in experimental testing and data analysis
- Knowledge in tribology in a plus

Personal characteristics:
- Autonomy
- A taste for teamwork
- A taste for experimental work

Financement : MESRI Etablissement

Dossier à envoyer pour le 27/05/2024
Début du contrat : 1er Octobre 2024
Salaire mensuel brut : 1975€

Direction de la thèse:/ **Thesis Supervisor**

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Encadrement de la thèse : **co-directeur(s) et co-encadrant(s)**

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Applicants are invited to submit their application to the PhD supervisors.
Application must contain the following documents:
- CV
- Cover letter
- At least 1 reference letter
- Transcript from Master, with ranking if available