Monday Morning, May 20, 2024

Tribology and Mechanics of Coatings and Surfaces
Room Palm 1-2 - Session MC1-1-MoM

Friction, Wear, Lubrication Effects, and Modeling I

Moderators: Carsten Gachot, Vienna University of Technology, Austria, **Giovanni Ramirez**, Zeiss Industrial Quality Solutions, USA

10:00am **MC1-1-MoM-1 Modern Analytical Methods for Characterizing Wear Surfaces and Subsurfaces*, Thomas Scharf (thomas.scharf@unt.edu),*** The University of North Texas, USA **INVITED**

It is now common to employ focused ion beam (FIB)-SEM and subsequent TEM characterization techniques to study 'site-specific' deformation structures. In this talk, I will highlight more underutilized diffraction and imaging techniques, such as Precession Electron Diffraction (PED)-TEM, Transmission Kikuchi Diffraction (TKD)-SEM, as well as 3-D FIB serial sectioning to interrogate subsurface structural evolution during sliding wear. *First*, new insights into solid lubrication mechanisms in directed energy deposition (DED) metal matrix composites (Ni/TiC/graphite) reveal that the improved tribological behavior is due to the in-situ formation of a low interfacial shear strength amorphous carbon tribofilm that is extruded to the surface through refined Ni grain boundaries. 3-D FIB serial cross-sectioning inside the worn surfaces of these composites revealed that the tribological stresses in the subsurface extrude the graphitic, primary carbon towards the surface through intergranular separation of refined nanocrystalline Ni grains. *Second*, surface and subsurface structural evolution during sliding wear of an in situ nitrided DED titanium alloy, Ti-35Nb-7Zr-5Ta (TNZT), was studied by cross-sectional TEM coupled with PED. Corresponding precession–orientation imaging phase maps were used to determine the orientation and percentage of α and β-Ti in the worn nitrided TNZT. The maps revealed that the nanocrystalline grains of soft/compliant β are much smaller (10-100 nm) than hard/stiff α grains (>100 nm). Wear reduction is due to the combination of the above phases and increase in the alignment of {0002}-textured coarser α grains along the sliding direction with absence of texture in the highly refined β grains. *Lastly*, I will show how coupled cross-sectional TKD-SEM can interrogate the microstructural evolution in a Co-Cr alloy sliding on a Ta-W alloy.

10:40am **MC1-1-MoM-3 Wear-Protection Performance and Durability of *in-Situ*-Deposited Carbon TribofilmsDerived from Intrinsically Strained Cycloalkane Molecules as Lubricant Additives***, Z. Al Hassan, H. Wise, T. Martin, S. Liu, Q. Wang,* ***Y. W. Chung (ywchung@northwestern.edu),*** Northwestern University, USA*; S. Berkebile,* US Army Research Laboratory, USA

Wear-protective coatings on tribo-component surfaces are usually applied *via* vapor deposition methods. Once worn, they can only be restored through component disassembly. In our study, we explored *in situ* carbon tribofilm deposition using intrinsically strained cycloalkane molecules. These molecules, when dissolved in lubricants, can induce tribopolymer formation under stress and temperature at asperities. Our previous work on cyclopropane-carboxylic acid (CPCa) as an additive in polyalphaolefin and dodecane demonstrated the successful deposition of micron-thick carbon tribofilms in 15 minutes during pin-on-disk testing with a ten-fold reduction in wear. New results show that even after the removal of CPCa from the lubricant, these tribofilms continue to provide wear protection for up to 40 hours. Detailed surface examination using Raman spectroscopy helps us unravel the underlying mechanism for such extended durability of these carbon tribofilms. This research suggests a unique approach to providing unlimited replenishment of wear-protective layers.

11:00am **MC1-1-MoM-4 Lubricant Interaction of Triboactive CrAlMoCuN Coatings in Steel Contacts***, K. Bobzin, C. Kalscheuer,* ***Max Philip Möbius (moebius@iot.rwth-aachen.de),*** Surface Engineering Institute - RWTH Aachen University, Germany

Conventional lubricants are designed for wear and friction reduction in steel-to-steel contacts. Rising power densities require enhanced wear resistance of machine components. This can be achieved using hard CrAlN coatings, although their chemical inertness limits interaction with lubricants. Therefore, Mo and Cu are incorporated into CrAlN coatings, promoting tribo-chemical interaction with lubricants. Mo can interact with sulfur to create MoS_2 tribofilms. Cu acts catalytically for this reaction and can enhance tribofilm formation for Fe_x-P_y and a-C. In most applications like gear boxes, bearings or chain drives, it is economically and technologically challenging to coat all components. Therefore, this study focuses on coating-steel contacts. Three CrAlMoCuN coatings and one CrAlN reference were deposited using physical vapor deposition (PVD). Coating characterization includes morphology, coating thickness, chemical composition, indentation hardness, surface roughness and compound adhesion. All coatings, along with an uncoated reference, were tribologically investigated using a pin on disk (PoD) tribometer. As substrate, the chain pin steel 58CrV4 was used, quenched and tempered to H = (52±1,5) HRC. The PoD parameters were an initial contact pressure of p_{PoD} = 1,400 MPa, a relative velocity of v_{rel} = 0.1 m/s, and a temperature of T_{PoD} = 70 °C. 100Cr6 steel was used as counterpart and Polyalphaolefin (PAO) as lubricant. PAO was highly additivated with sulfur and phosphorous. Tribofilms were investigated using energy dispersive spectroscopy (EDS) and Raman spectroscopy. All CrAlMoCuN systems showed lower coefficients of friction compared to both references indicating the formation of MoS_2 containing tribofilms. This correlates with a significantly reduced total wear volume.Via EDS, Cu-enriched lubricant residues were found on the uncoated counterparts in the CrAlMoCuN system, indicating the interaction of Cu with the lubricant in the tribological contact for the first time. The results show high potential of CrAlMoCuN coatings for lubricated machine element applications.

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