Insights of material flows under shearing and pressure

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Abstract

Wear processes result of chemical-physical-mechanical phenomena: material transformation, particles detachment and material flows at the contact interface. Tribological scenarios are defined by different factors: materials properties, chemical environment, thermo-mechanical stresses as a result of loading and contact conditions, leading to the balance between the different matter flows (source, internal, recirculation or ejection out of the contact). Experimental evidence highlights that dry sliding contacts are characterized by the presence of a third body, i.e. a layer of solid material, trapped in the contact interface. But the dynamic behavior of this third body in the case of dry contacts is difficult to study in situ, as a contact is a confined system, inaccessible to direct local measurements. The idea, therefore, is to study those materials outside a contact, with controlled loadings and under (thermo)mechanical conditions representative of a contact. The HPT (High Pressure Torsion) test, a severe plastic deformation process, is used for this purpose. It has the advantage of reproducing, in the samples, conditions close to those found locally in contacts, i.e. shear and pressure, for continuous materials (2-5) but also for granular materials (6-8).
A custom-built HPT test bench has been designed at LaMCoS to be implemented on a double X-ray tomograph (DTHE). X-ray tomography has the advantage of being a non-destructive method for reconstructing the composition and internal structure of an object in three dimensions from several X-ray images. The coupling of these 2 methods, HPT and tomography, allows to monitor *in situ* the local evolution of a model interface sheared under pressure, from the point of view of its flow and structural (re)organization (segregation, density gradients, mixture formation, etc.).

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In this communication, the experimental results with 3 different granular model third bodies (a poly-dispersed steel powder, a mixed of steel and carbon powder, a mixed copper and tungsten carbide powder, ie.e. Cu 85wt% / WC 15wt%) are presented. The tests are performed under ambient air, 5 contact pressures up to 1 GPa, 3 rotation speeds. The volume of material sheared is consistent with that of the third body found in the contacts. The chemistry, shape, size, mechanical properties, surface properties, etc. of selected particles are related to real contacts. Rheological properties and microstructural organization and modification are analysed as a function of deformation paths and initial particle properties. The 4D reconstruction procedure is also discussed.

REFERENCES

(1) S. Descartes and al., An attempt to produce ex situ TTS to understand their mechanical formation conditions – The case of an ultra-high purity iron, Wear, 271(9-10), (2011) 1833-1841

(2) S. Descartes and al., Inhomogeneous microstructural evolution of pure iron during high-pressure torsion, Materials Science and Engineering A, 528, (2011) 3666–3675

(3) J. M. Shockley and al., Significance of Al2O3 particle morphology in the microstructure evolution of cold-sprayed Al-Al2O3 during unconstrained high-pressure torsion, Materials Science and Engineering: A, 684, (2017) 510-516

(4) Y. Zhang and al., Microstructural evolution and mechanical properties of ultrafine-grained pure α-iron and Fe-0.02%C steel processed by high-pressure torsion: Influence of second-phase particles, Materials Science and Engineering: A, 795, (2020), 139915

(5) A. Bachmaier and al., New procedure to generate stable nanocrystallites by severe plastic deformation, Scripta Materialia 61 (2009) 1016–1019

(6) S. Panda and al., Effect of initial powder type on the hydrogen storage properties of high-pressure torsion consolidated Mg, International Journal of hydrogen energy 42 (2017) 22438-22448

(7) J. Sort and al., Microstructural effects and large microhardness in cobalt processed by high pressure torsion consolidation of ball milled powders, Acta Materialia 51 (2003) 6385–6393

(8) Y. Zhang and al., Tribologically induced nanolaminate in a cold-sprayed WC-reinforced Cu matrix composite: a key to high wear resistance, Materials and Design 182 (2019) 108009