FROM MIRCO-MECHANICAL PROPERTIES TO TRIBOLOGICAL PERFORMANCE

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Abrasive contacts are still too complex to allow reliable predictions of part performance. There is not a single material model with satisfying generality, yet. However, it should be a combination of the contact body's relative elastic and plastic properties as well as the loading condition.[1] In industry carbide- and boride-reinforced, metal matrix composites are often cladded on a base part with welding processes to counter abrasive wear. These composites generally pose structural features at a multitude of length scales. A millimeter thick coating is reinforced with carbides of 100 µm diameter. Precipitates of 1 to 10 µm decorate the matrix and during the major solidification, a metal-stable carbide-metal eutectic forms with domains widths of 1 µm and 100 – 200 nm lamella spacing.

This meso-structure renders materials description, modelling and testing challenging. There are two main types of challenge: For one, the number of features and their orientations cannot be simplified to the usual suspects of grain size, orientation and boundaries. Therefore, the amount of data required running meaningful calculations on complex loading conditions such as wear is impractically large on current computer systems. This makes experimental testing a key element in material development and qualifications.
The second challenge originates in the size of the plastic zones and the structural arrangement of brittle, semi-brittle and ductile phases. The structure of composites generally makes it difficult to predict properties at other lengths scales than tested. In fine structured ductile-brittle laminates, the ductile zone of the ductile phase is significantly larger than the phase itself.

In the current work, we investigate scale effects of micro- and meso-mechanical properties, such as modulus, hardness and fracture toughness to understand the complex loading conditions of abrasive wear. We are using large indentation datasets and mechanical mapping, as well as pillar splitting and notched bending bars. Our indentation data sets of more than 100k indents obtained at micrometer lateral resolution open a new way to study meso-scale mechanical properties and the underlying laws of mixing.

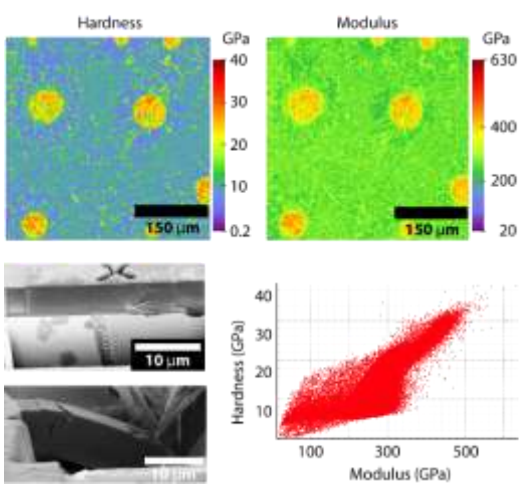

Figure 1 – Nano indentation mapping at 500 nm lateral resolution resolves the precipitated carbide microstructure and mechanical properties in technical hard facing alloys. Coupled with size depended fracture toughness measures, this renders a framework to find new wear models and optimize tribological performance.

With the ability to control the displacement in crack propagation, we are further able to crack specific phases in a controlled manner. This enables us to put together a map of wear performance for a material model of our choice.
While we generally focus on laser-cladded superalloy-tungsten carbide composites, novel hard carbide phases have recently attracted our attention. The novel binary carbide $(W,Ti)C_{x-1}$ has recently been found to exhibit a behavior similar to the MAX Phase. These carbides, of a transition metal and a IIIA or IVA metal, have potential to improve toughness in ceramics[2], to be used as a light weight high temperature conductor and for abrasion resistance. A new phase has been reported in the ternary W-Ti-C system.[3] No micromechanical data is available on its mechanical properties. We used pillar compression and splitting at different sizes to study the binary carbides size effect in modulus, hardness and toughness. We propose a workflow for data driven anti-wear coating development.

[1] Meng and Ludeman, Wear, 181-183, 1995
[2] Barsoum and Radovic, An. Rev. o. Mat. Res., 41, 2011
[3] Anasori et al., Inorg. Chem, 58,2019