SMALL SCALE MECHANICAL BEHAVIOUR OF WC-Co CEMENTED CARBIDES: NANOINDENTATION, FIB TOMOGRAPHY AND NUMERICAL MODELLING

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Abstract

Cemented carbides, also known as hard metals, are materials widely used in forming, metal and wood cutting as well as mining operations. They are generally composed of two interpenetrating phases: a hard WC ceramic phase and a metallic binder, usually a Co alloy. Understanding and modelling the micromechanical behavior is key to enhance performance in engineering applications. However, numerical models based on continuum assumptions, or in idealized simplistic microstructures fail to capture the complex behavior of these materials and to stablish robust methodologies for behavior prediction and implementation of alternative compositions.

In this work, we attempt to link experimental micromechanical testing with numerical model using realistic microstructures. First, we produce a tomography by focused ion beam of the material, segmenting both phases. This tomography is them meshed to produce realistic reconstructions of the microstructure. Micromechanical data is acquired by nanoindentation, high-speed nanoindentation, microcantilevers, micropilars and microtesile tests and used as imputs for modelling.

Using these experimental imputs, two deterministic models are used: Microplane J2 Plasticity for the ductile Co phase and Model M7WC for the hard WC phase. Once these deterministic models are in place, we delve into the stochastic behavior of these composites at the small specimen level. At this scale, the material faces significant uncertainty due to random assembly of its constituent phases, variations in crystal orientation of WC grains, intrinsic residual stresses, and variable confinement by the metallic binder. To address this uncertainty, we introduce a Stochastic Model that complements the deterministic ones. This model incorporates an autocorrelated grafted Gaussian-Weibullian distribution to capture expected variations in local strength. Numerical predictions are then contrasted with complementary experimental micromechanical tests (micropillar compression) as well as macroscopical strength data, achieving an excellent agreement.

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