Understanding nanoindentation statistical dispersion in ceramic – metal cemented carbides by numerical simulation and FIB tomography

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Abstract

WC-Co composites are metal-ceramic composites that have a dual-phase structure composed of a hard carbide phase (WC) and a metallic binder phase (usually Co). When characterized using high-speed nanoindentation, these contrasting phases lead to significant variability in hardness measurements of each phase. Such variability is influenced by the interaction between the phases and the contribution of subsurface microstructural features. To better understand and quantify this phenomenon, this study integrates simulated nanoindentations, based on three-dimensional reconstructions from FIB tomography, with experimental data to correlate hardness values with the microstructural characteristics of the composite. The given approach seeks to relate the percentage of binder present in the zone near the contact point versus the hardness given in the simulation. This binder percentage gives information of the local microstructural surroundings influencing the indentation response. This is possible because the subsurface microstructure is fully characterized in the simulations. When performing experimental data, where this cannot be observed, the expected results are expected to be different. The percentage of binder present on the surface near the contact point will also be studied to know the importance of the material under the visible surface.

Once the nanoindentation conditions have been determined, a first approximation to the study area is determined by looking for the distance of affectation in the direction normal to the surface. This is done using a simpler model of thin layer and observing the evolution of the hardness as the thickness of the layer of the surface material is reduced. Next, meshes with the real microstructure are generated using three-dimensional reconstruction after FIB tomography. For each indented zone, the percentage of three-dimensional and two-dimensional binder is obtained using the distance previously obtained. The hardness is

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plotted with respect to the percentage of binder and the relationship that follows is analyzed. Other studies regarding the shape of the curve can be made.

Experimental tests are then performed. A small indentation map is made and a SEM image is made in order to obtain the two-dimensional binder percentage. The correlation between the data obtained by simulation and the experimental data is studied. For the three-dimensional study, a FIB tomography of the nanoindentations is performed.
Results show a good simulated force-displacement curve from which the hardness can be obtained. It has also been possible to plot hardness maps equivalent to those seen experimentally. A very clear relationship can also be seen between the percentage of volumetric binder and the recorded hardness. The dispersion of the data increases when the percentage of surface binder is used, showing that it is not possible to relate in a direct way what is seen on the surface with the expected mechanical properties. This study shows the importance to use statistical analysis and numerical simulations to correctly extract mechanical properties of different phases in high speed nanoindentations maps.