Fall 10-5-2015

Measuring the fracture toughness of Titanium Carbide reinforcements at the micronscale

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It is known that the mechanical properties of composite materials and alloys are strongly influenced by the intrinsic mechanical properties of their reinforcements or second phases. Such local properties are difficult to measure in particulate reinforcements or second phases because of the irregular shape and small size of material samples to be tested. We compare three methods that measure the fracture toughness of TiC reinforcements by combining focused ion beam (FIB) milling methods with nanoindentation techniques and finite element simulation. In-situ created TiC particles in a steel matrix are tested. Such particles are analysed by EBSD to select the crystalline orientation. The first method is a classical nanoindentation toughness measurement test based on the instrumented nanoindentation of inclusions using cube corner indents under a load of 13 mN, so as to nucleate radial cracks. The toughness is then calculated with the Lawn equation. The second and third methods are based on the production and testing of microbeams. Selected particles are micromachined using FIB milling, creating a notched beam. The notch is either a straight-through notch or a chevron-notch. A nanoindenter equipped with a cube corner diamond tip is then used to apply a force at the end of the beam. The deformation of each notched beam is modelled using finite element analysis, on the basis of prior examination and measurement of its characteristic dimensions. From this, the fracture toughness is determined by means of each of these three methods, and compared.