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Analysis of deformation mechanisms in Ni-based cemented carbides by means of micropillar compression and Machine Learning techniques

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Cemented carbides are multiphase materials constituted by a hard ceramic phase, commonly tungsten carbide (WC), embedded in a metallic matrix, being the mostly used Co. The mechanical properties achieved from these two constitutive phases, including an excellent hardness, strength, toughness, wear and abrasive resistance, makes the WC a highly demanded material for industrial applications, such as cutting tools, molds, mining parts or industrial nozzles, among others. However, cobalt is considered as a Critical Raw Material (CRM) and carcinogenic-mutagenic and toxic to reproduction material (CMR), hence new alternatives are emerging, being the most promising one the nickel due to its similarity –in terms of mechanical, electrical and chemical properties –and an improved corrosion resistance. Despite this situation, cemented carbides with Ni-based metallic matrix remain unstudied, including its mechanical behavior under stress, strongly influenced by the surrounding deformation mechanisms between its constitutive phases.

The micropillar compression technique enables the application of a controlled stress to a small volume of material, allowing the deformation mechanisms to be reproduced and analyzed through the stress-strain curves. Moreover, when using an in-situ nanoindenter, the live SEM monitoring of the micropillars during the experiment allows the accurate correlation of the pop-in events, visible in the stress-strain curves, with the different deformation mechanisms. Establishing the proposed correlation becomes particularly relevant when examining its dependence on other variables, such as testing temperature. Since different deformation mechanisms are expected to operate under varying thermal conditions, this correlation offers a valuable means of distinguishing between them.

As all the aforementioned procedures can be time-consuming, Machine Learning is expected to improve the efficiency of the analysis by 1) facilitating the identification of pop-in phenomena in the stress-strain curves, 2) facilitating the identification of deformation mechanisms in the live SEM monitoring and 3) automating the procedure of correlating pop-ins and deformation mechanisms. An additional area for improvement with Machine Learning techniques could be the cross-section analysis by means of Deep Learning, to automate the identification of deformation mechanisms through cross-section images of the post-mortem micropillars.

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