Enhancing the information-richness of Berkovich nanoindentation testing to extract slip systems interaction parameters from residual topographies and crystal lattice rotations on FCC crystal using inverse method

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Abstract

The single-crystal plasticity framework allows microscale effects to be described from a continuum mechanics point of view, enabling large-scale simulations of great interest in the nuclear and aeronautical fields. Among these parameters, the determination of the coefficients governing the interactions between the slip systems, the core of the plasticity laws, is crucial for reliable simulations applied to industrial fields. However, these parameters are difficult to determine experimentally.

The nanoindentation test seems to be a good choice to improve the identification of the interaction coefficients using the FEMU (Finite Element Model Updating) method. The 10 hardening parameters of the Méric-Cailletaud law of behavior must be identified simultaneously using FEMU to correctly describe the hardening behavior of a material. In order to optimize and improve the identification process, a prior identifiability study is performed to construct an optimal experimental design. The identifiability analysis measures the information richness that could be given to the identification process, leading to better control of the future identification process.

In this study, a numerical study of the information-richness of Berkovich nanoindentation observables will be investigated. The identifiability of crystal plasticity parameters, including interaction coefficients, is investigated using a set of parameters obtained in a previous study, considering crystal lattice rotation, residual topographies, and their combinations. Berkovich nanoindentation simulations and experiments are carried out on single crystal nickel samples. We investigate experimental crystal orientations and the relative orientation between crystal reference frames and the Berkovich tip to simulate the nanoindentation test. The identifiability analysis, allowing the quantification of the information-richness, is based on an

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I-index, a scalar that transcribe the local convexity of the cost function. It allows comparing the information-richness contained in each experiment and combinations of experiments in order to define an optimal design of experiments.