ENHANCING THE INFORMATION CONTENT OF BERKOVICH NANOINDENTATION TESTING TO EXTRACT SLIP SYSTEM INTERACTION COEFFICENTS FROM RESIDUAL TOPOGRAPHIES AND CRYSTAL LATTICE ROTATIONS ON FCC CRYSTAL USING INVERSE METHOD

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ABSTRACT

The single-crystal plasticity framework enables microscale effects from a continuum mechanics perspective, thereby allowing to perform large-scale simulations in fields such as nuclear and aerospace. Among the parameters governing these frameworks, the identification of the coefficients that control the interactions between the slip systems, the core of the plasticity laws, is crucial for reliable simulations in industrial application. However, determining these coefficients through experimental validation remains a significant challenge.

Nanoindentation test offers a promising approach for improving the identification of the interaction coefficients using the FEMU (Finite Element Model Updating) method. Specifically, the 10 hardening parameters of the Méric-Cailletaud law [1] must be identified simultaneously to accurately describe a material's hardening behaviour. Previous studies showed the sensitivity and identifiability of 9 crystal plasticity parameters (including 6 interaction coefficients) using residual topographies obtained from Berkovich nanoindentation tests [2], [3]. Building upon their work and including a 7th interaction parameter as proposed by Madec and Kubin [4], 10 crystal plasticity parameters were identified using residual topographies from Berkovich nanoindentation [5]. However, only a moderate conditioning of the inverse problem was achieved, despite the use of a diverse and representative database composed of eleven different crystallographic orientations. To improve the conditioning of the inverse problem, additional information extracted from the nanoindentation may be required.

The present study therefore aim to design future experiments to identify crystal plasticity parameters, including interaction coefficients, while seeking enhanced conditioning of the inverse problem compared to our previous study [5]. The key design parameter is the information content of Berkovich nanoindentation observables and their combinations. The information content is quantified through an identifiability analysis of the targeted crystal plasticity parameters based on the observables and their combinations, using a reference parameter set established in [5]. This study evaluates the identifiability of observables obtained both beneath the surface (crystal lattice rotation) and on the surface (residual topographies) after the nanoindentation test, as well as their combine use. Berkovich nanoindentation simulations and experiments are carried out on single crystal nickel samples. A set of 13 orientations, chosen to discretize the inverse pole figure, will be investigated. Finally, by exploring the database of observables across 13 orientations, the optimal set of experiments will be determined.

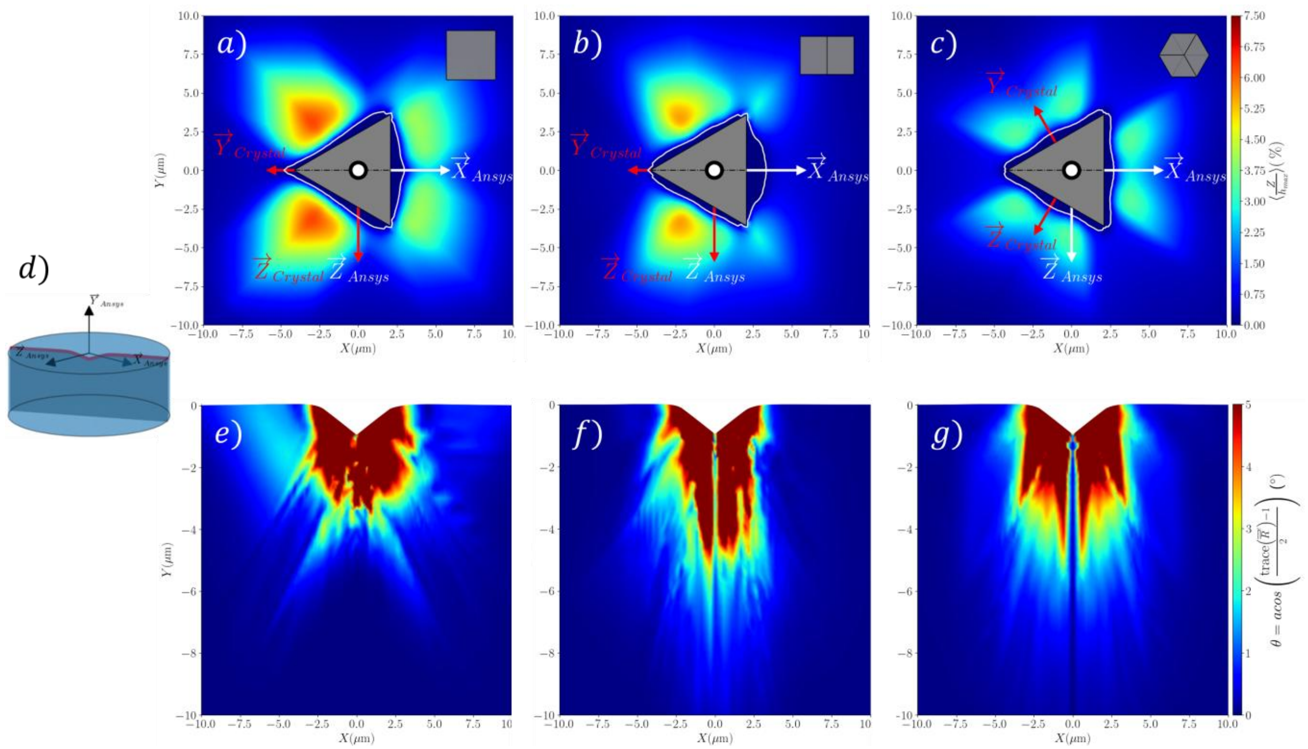

Figure 1 : Nanoindentation simulated topographies and lattice rotation fields using the reference set of parameters established in [5]. From a) to c) residual topographies obtained from nanoindentation simulations using the orientations [100], [101] and [111], respectively. From e) to f) are represented slices of the lattice rotation field beneath the surface for each orientation. The position of the slice is represented in d), and the in-plane orientation of the indenter is illustrated with the topographies. A cube shape representing the crystal orientation is illustrated along with the topographies.

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