

ENHANCING THE INFORMATION-RICHNESS OBTAINED FROM BERKOVICH NANOINDENTATION TO QUANTIFY SLIP SYSTEMS INTERACTIONS IN FCC CRYSTAL

Alexandre Bourceret¹, Yves Gaillard¹, Arnaud Lejeune¹ and Fabrice Richard^{1(*)}

¹Université de Franche-Comté (Besançon), Institut FEMTO-ST, CNRS/UFC/ENSMM/UTBM

(*)email : fabrice.richard@univ-fcomte.fr

ABSTRACT

Determination of the slip systems interaction coefficients ($h_i, i \in \{1, \dots, 7\}$), plasticity laws core, is critical for reliable simulations applied to industrials fields. Those parameters are difficult to identify experimentally. Nanoindentation test seems to be a great choice for enhancing slip systems interaction identification (Renner et al., 2016, 2020). Nevertheless, the inverse method used to identify those parameters requires a Crystal Plasticity Finite Element Model of the test which is sustainable with the fewer computation time possible. The 10 hardening parameters (Q, b, τ_0 and h_i) must be identified simultaneously. To optimize and enhance the identification process, a prior identifiability study is performed to build an optimal experimental design. Identifiability study measure the information richness that could be given to the identification process using Finite Element Model Updating method.

Firstly, indentations simulations and experiments are performed within a single grain. We investigate the experimental crystal orientations and the relative orientation between crystals references frames and the Berkovich tip to simulate the nanoindentation test in the same configuration than the experimental one. To highlight the impact of the slip systems interactions coefficients on residual topographies, we first used three sets of interaction from literature (Madec & Kubin, 2017; Méric et al., 1994). Using those three sets of parameters, figure 1d) to f) illustrates the sensitivity of the residual topography to the interaction coefficients. We can observe on Figure 1 the difference between the three topographies in terms of height, shape and distribution of pile-ups. These simulations highlight the sensitivity of the topography and $P - h$ curve to the interaction coefficients.

To quantify the information richness, an identifiability analysis from some observables ($P - h$ curves, topographies) and tip/crystal experimental orientations is performed. The quantification of the information richness is based on an I-index (Renner et al., 2020). This I-index measures the parameters identifiability (i.e., the sensitivity of a set of parameters to the observables). It allows to compare the information-richness contained in each experiment and combinations of experiments.

This result will lead to an optimal experiment design, providing enough information to well-pose the inverse problem.

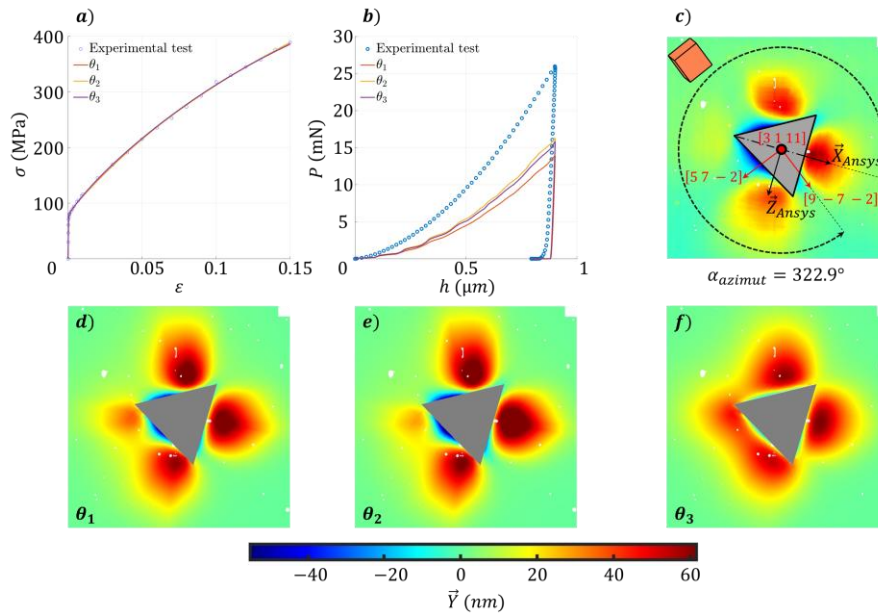


Figure 1 : a) Simulations and experimental tensile curves on polycrystal sample. b) Simulations and experimental $P - h$ curves. c) Crystal (red axis)/indenter tip configuration represented on the experimental topography. The $\vec{X}$ and $\vec{Z}$ component define the indentation plane and $\vec{Y}$ the elevation. Crystal orientation is illustrated by a cube shape in the upper left corner. Figures d) to f) are the simulated topographies for the three θ_i sets of parameters.

KEYWORDS

Cristal Plasticity Finite Elements Model, Interaction matrix, Nanoindentation, Identifiability, Optimal experiment design

REFERENCES

- Madec, R., & Kubin, L. P. (2017). Dislocation strengthening in FCC metals and in BCC metals at high temperatures. *Acta Materialia*, 126, 166- 173
- Méric, L., Cailletaud, G., & Gaspérini, M. (1994). F.E. calculations of copper bicrystal specimens submitted to tension-compression tests. *Acta Metallurgica et Materialia*, 42(3)
- Renner, E., Bourceret, A., Gaillard, Y., Amiot, F., Delobelle, P., & Richard, F. (2020). Identifiability of single crystal plasticity parameters from residual topographies in Berkovich nanoindentation on FCC nickel. *Journal of the Mechanics and Physics of Solids*, 138
- Renner, E., Gaillard, Y., Richard, F., Amiot, F., & Delobelle, P. (2016). Sensitivity of the residual topography to single crystal plasticity parameters in Berkovich nanoindentation on FCC nickel. *International Journal of Plasticity*, 77, 118- 140.