“CRYSTAL PLASTICITY MODELING OF THE DEFORMATION OF BCC IRON AND NIOBIUM SINGLE CRYSTALS”

By: Aboozar Mapar
Advisors: Dr. Farhang Pourboghrat & Dr. Thomas Bieler

The conventional Schmid-type crystal plasticity models cannot predict the deformation of BCC polycrystals or single crystals. Therefore, in this study, a non-Schmid crystal plasticity model was developed for single crystal ferrite which has a BCC structure. The average error of this model in predicting the force-displacement response of these ferrite single crystals is 4.3%, while the average error of the Schmid-type crystal plasticity model is 10.1%.

To address the shortcomings of the conventional Hill-type hardening rule, two novel hardening models were derived, developed, and compared to the classical hardening rule. These models are named the Differential-Exponential and the Dynamic hardening rules.

The Differential-Exponential hardening rule was implemented into the non-Schmid crystal plasticity model. This model was then used to predict the deformation behavior of the single crystal ferrite micropillars that show stage I and stage II hardening. The average error of this model in predicting the force-displacement of these ferrite micropillars is 3.7%.

The Dynamic hardening rule was implemented into the Schmid-type crystal plasticity model. This enabled the crystal plasticity model to accurately predict the deformation behavior of Nb single crystals. The average error in predicting the stress-strain curves using the Schmid-type crystal plasticity model and the Dynamic hardening rule is 6.7%, while this error with the classical hardening rule is 8.5%.

Finally, the hydroforming of an oligo-crystal Nb tube with several large grains was simulated with the Schmid-type crystal plasticity model and the Dynamic hardening. The goal was to assess the accuracy of the new hardening model in simulating the tube hydroforming process where the material undergoes the more complex biaxial deformations. Qualitatively, the model predicted the location of the crack and the areas with significant circumferential strain in the hydroformed tube effectively.