8th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMA2022)
June 5-9, 2022, Oslo, Norway

DATA-DRIVEN SURROGATE MODEL FOR PLASTIC ANISOTROPY IN HCP METALS BASED ON THE BEHAVIOR OF MG POLYCRYSTALS

YANNICK HOLLENWEGER *, BURIGEDE LIU †

* Mechanics and Materials Research group, Department of Mechanical and Process Engineering, ETH Zürich, 8000, Zürich, Switzerland
†Data-driven mechanics research group, Department of Engineering, University of Cambridge, CB2 1PZ, Cambridge, U.K.

Key words: Anisotropy, plasticity, data-driven, surrogate models.

ABSTRACT

Magnesium (Mg) alloys have experienced an increased level of interest in past years due to their prospective use as light-weight alternatives to steel and aluminum. At lower temperatures, Mg alloys exhibit poor ductility and formability. The behavior of Mg is strongly anisotropic and hinges upon the activation of a variety of strongly disparate deformation modes including slip and twinning. At elevated temperatures, the anisotropy is reduced and better ductility is exhibited, due to the ready availability of an increased number of slip deformation modes of the hexagonal lattice at elevated temperatures. A number of continuum and multiscale constitutive models were developed to capture the plastic behavior of hcp materials, to which Mg are associated, and were able to capture the deformation behavior with great success. The plastic deformation of Mg, however, poses a number of challenges to the theoretical and especially numerical nature of classical constitutive approaches. The disparity and severe anisotropy in Mg plasticity and the reorientation of the lattice due to twinning, which is prevalent at all investigated temperatures, affect the stability of physically informed approaches and leads to computational bottlenecks in the computation of the visco-plastic updates.

A way to circumvent the computational limitations is by making use of trained, data-driven surrogate models. These methods may either be direct, i.e. predicting the stress related to a strain path, or indirect, meaning they learn the operators associated with the evolution of the internal variables at a given deformation history. We present an indirect, data-driven Ansatz to predict the anisotropic plastic response as well as the texture evolution of Mg including twin reorientation during plastic deformation processing. The Ansatz learns the operator associated with the updates of the history-dependent variables under arbitrary deformation and circumvents time-consuming updates linked with the evolution of twin and slip activity in crystal plasticity models. It also learns the texture evolution associated with the microstructure evolution of the material and predicts the texture changes in polycrystalline samples of pure Mg.