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HIGH-RESOLUTION COMPUTATIONAL PLASTICITY AT THE MICRON SCALE

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ABSTRACT

The persistent demand for green, strong and ductile advanced high strength steels, with a reduced climate footprint, calls for novel and improved multi-phase microstructures. The development of these new steels requires an in-depth understanding of the governing plasticity mechanisms at the micron scale. In order to address this challenge, novel numerical-experimental methods are called for that account for the discreteness, statistics and the intrinsic role of interfaces. This lecture sheds light on recent and innovative developments unravelling metal plasticity at the micron scale:

- *Computationally assisted high-resolution micron-scale experiments*: multi-phase through-thickness samples allow for a full characterization of the underlying microstructure. Using computational crystallographic insights, a slip system based local identification method has been developed [1], which provides full-field crystallographic slip system activity maps. The resulting deformation maps are directly used to assess the model predictions.
- *Discrete slip plane modelling to analyze heterogeneous micro-scale plasticity* [2]: Heterogeneous spatial variations are introduced by sampling the slip system properties of individual atomic slip planes from a probability density function. This allows ro recover naturally localized slip patterns with a high resolution. It is demonstrated that this discrete slip plane model adequately replicates the diversity of active slip systems in the corresponding experiment, which cannot be achieved with standard crystal plasticity models.
- *Internal boundaries or interfaces in multi-phase steels*: Recent experimental observations on dual-phase steels (with martensite as the hard phase) demonstrate substructure boundary sliding parallel to the habit plane in lath martensite. To address this important small-scale phenomenon, a habit-plane slip enriched laminate model is developed. This model adequately captures the role of the substructure boundary sliding on the deformation of the martensite aggregate.
- *Integrated experimental-numerical framework, applied to dual-phase (DP) steels*: This framework is employed to unravel the discreteness of ferrite plasticity, the degree of plastic anisotropy in martensite and the potential of direct damage modelling in DP steels.

- *A homogenization framework for interfaces in dual-phase steels:* This homogenization methodology has been developed to upscale the influence of discrete slip events in martensite (along the habit plane), impeding at the martensite-ferrite interface where damage accumulates [3].

These recent developments in computational plasticity at the micron scale enable a proper understanding of the physical origin of micro-scale phenomena, and thereby contributes to the development of the next generation of green steels, for which recycling and alternative production methods will become of paramount importance in the future.

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