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Assessing local ductility of dual-phase steel microstructures – a systematic micromechanics study

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Abstract

Advanced high-strength steels often have microstructures which consist of multiple phases. The classical motivation behind such designs is to combine a hard but brittle phase with a softer, more ductile one in order to mitigate the well-known strength–ductility trade-off. However, experimental studies show that some multi-phase steel grades can exhibit premature failure during edge shearing, a loading condition which challenges the local ductility of the material. In some cases, single-phase brittle steels outperform multi-phase steels in these tests, despite exhibiting inferior global ductility. These tendencies are known but not well understood. Adding further complexity, complex-phase steel microstructures, containing more than two phases, can overcome this apparent contradiction [1]. In this work, we investigate these phenomena at an abstract level by modelling idealized three-dimensional microstructures. The focus is placed on identifying the key microstructural features governing local ductility, namely phase contrast, phase volume fraction, and the intrinsic ductility of the individual phases. The proposed model represents microstructures as three-dimensional representative volume elements with randomly distributed material properties and is computationally efficient enough to explore large parameter spaces. By assigning distinct, competing failure mechanisms to each phase, the model enables not only the prediction of the onset of microstructural failure, but also the identification of the dominant failure mode. In particular, it allows tracking which phase and which local regions fail first, and how it accumulates to macroscopic fracture. This simplified framework makes it possible to systematically analyse broad microstructure spaces and to identify critical combinations of microstructural parameters that govern ultimate failure.

Keywords:

Dual-phase steels Micromechanics Local ductility Damage Fracture