Parameterization of a Nonlocal Crystal Plasticity Model for Tempered Martensite by Nanoindentation and Inverse Modeling

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ABSTRACT

Tempered martensitic steels are a widely used material for structural applications. Their microstructure is hierarchical with sub-units of laths, blocks, and packets that appear in prior austenite grains (PAGs) during quenching [1]. This material is inherently brittle, because the crystal structure of the as quenched material exhibits a strong tetragonal distortion. During tempering, however, the tetragonal distortion is relieved. Despite its large number of applications, there is still no quantitative understanding of the microstructure-property relations. Thus, we propose a model that considers the influence of complex microstructural features on the mechanical response of the material. This model is based on a non-local crystal plasticity formulation that captures the influence of deformation gradients occurring for example at grain boundaries or during nano-indentation [2]. One major drawback of this nonlocal model and other micromechanical models is the rather large number of material parameters necessary to describe material specific behavior. Furthermore, guidelines to determine all these material parameters are still limited. Therefore, a standardized parameterization technique should be discussed in the micromechanics community to promote applications of the nonlocal crystal plasticity models.

This study aims to propose a parameterization technique for the nonlocal crystal plasticity models of tempered martensite using the nanoindentation test. First, the nanoindentation test using cono-spherical indenter tip is performed on packets in the tempered martensitic microstructure and the resulting surface topology is characterized. Second, simulation of the indentation process with approximated parameters is performed and the experimental and simulated surface topologies and force-displacement curves are compared. In an iterative procedure, the model parameters are adapted to yield an optimal agreement between experiment and simulation. This inverse method has been successfully tested for microhardness tests [3] and will now be transferred to nanoindentations that offer the possibility to characterize very small volumes of material. Consequently, a fully parameterized micromechanical model for tempered martensite can be built, which will support us in our understanding of microstructure-property relationships.

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