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A Micromechanical Constitutive Model for Anisotropic Cyclic Deformation of Super-elastic NiTi Shape Memory Alloy Single Crystals

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Abstract

Based on the experimental observations on the anisotropic cyclic deformation of super-elastic NiTi shape memory alloy single crystals done by Gall and Maier (2002), a crystal plasticity based micromechanical constitutive model is constructed to describe such anisotropic cyclic deformation. To model the internal stress caused by the unmatched inelastic deformation between the austenite and martensite phases on the plastic deformation of austenite phase, 24 induced martensite variants are assumed to be ellipsoidal inclusions with anisotropic elasticity and embedded in the austenite matrix. The homogeneous stress fields in the austenite matrix and each induced martensite variant are obtained by using the Mori-Tanaka homogenization method. Two different inelastic mechanisms, i.e., martensite transformation and transformation-induced plasticity, and their interactions are considered in the proposed model. Following the assumption of instantaneous domain growth (Cherkaoui et al., 1998), the Helmholtz free energy of a representative volume element of a NiTi shape memory single crystal is established and the thermodynamic driving forces of the internal variables are obtained from the dissipative inequalities. The capability of the proposed model to describe the anisotropic cyclic deformation of super-elastic NiTi single crystals is first verified by comparing the predicted results with the experimental ones. It is concluded that the proposed model can capture the main quantitative features observed in the experiments. And then, the proposed model is further used to predict the uniaxial and multiaxial transformation ratchetting of a NiTi single crystal.