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A thermomechanically coupled finite-strain constitutive model for cyclic pseudoelasticity of polycrystalline shape memory alloys

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Abstract

This paper presents a new 3D thermomechanical finite-strain constitutive model for cyclic pseudoelasticity of polycrystalline shape memory alloys (SMAs). The model considers four primary characteristics related to the cyclic behavior of SMA that have not been integrally addressed within the finite-strain framework: (i) large accumulated residual strain that results from the residual martensite and dislocations slipping during cycling; (ii) degeneration of pseudoelasticity and hysteresis loop due to the increase of dislocation density and internal stresses with the number of cycles; (iii) rate dependence that can be attributed to the thermomechanical coupling effect; (iv) evolution of the phase transformation from abrupt to smooth transition, as a consequence of the diversified crystallographic orientations of the grains, the heterogeneity of internal stresses, and the presence of non-transforming precipitates during cycling. Based on the decomposition of finite Hencky strain into elastic, transformation, residual and thermal components, the model is constructed within a thermodynamically consistent framework. Evolution equations associated with the internal variables are derived from the reduced form of energy balance, the Clausius-Duhem form of entropy inequality, and a Helmholtz free energy function that includes elastic, thermal, interaction and constraint energies. The model is used to simulate the

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