Micromechanics inspired, phenomenological model of fully coupled plasticity, phase transformation, and martensite reorientation in shape memory alloys

Stebner, Aaron, astebner@mines.edu, Colorado School of Mines, United States; Bhattacharya, Kaushik, California Institute of Technology, United States

ABSTRACT

Many models have been developed for simulation of shape memory alloy (SMA) constitutive responses. The historical development of these models has shifted as fundamental understanding of the physics of SMAs has been advanced: from a focus on transformation behaviors in isolation to the study of cyclic deformations and fatigue, i.e., coupled transformation and plasticity. The motivation for the model we present in this study was to arrive at a single, unified model capable of simulating rate-independent, thermo-mechanical shape memory behaviors, and their coupling to plastic deformation with high computational efficiency. In formulating an energy landscape at a macroscopic scale that encompasses elastic, initiation, and saturation of phase transformation, martensite reorientation, plasticity, and the coupling of plasticity with phase transformation and martensite reorientation terms, and then deriving an implicit, variational discretization of the equations, we achieved this goal. Furthermore, the use of invariant-based transformation surfaces allows us to simulate processing textures that range from random (i.e., as-cast ingot) to transversely anisotropic (i.e., rod, wire, tube) with no additional computational expense. In this presentation, we will review the model framework. Calibration and verification of the model will be illustrated through simulation of empirical data sets that include proportional and nonproportional axial-torsion loading and cyclic tensile deformation to moderate (~10%) strains. Furthermore, we will verify the evolution of the martensite volume fraction simulated by the model with in-situ diffraction experimental data.