Twin branching in shape memory alloys: a 1D continuum model with energy dissipation effects

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ABSTRACT

Refinement of twin spacing near the macroscopic austenite-twinned martensite (A-MM) interface in martensitic transformations in shape memory alloys has been experimentally observed [1]. This phenomenon arises from the reduction of elastic strain energy localized in the A-MM interface, albeit at the expense of increased interfacial energy. Early theoretical analyses, such as those by Kohn and Müller [2], provided insights into the scaling law governing branched microstructures constructed in a self-replicating pattern. More recently, Seiner et al. [3] introduced a discrete model focusing on estimating the elastic strain energy and interfacial energy contributions of branched microstructures, along with prediction of the number of branching generations required to minimize the total energy.
In this study, we introduce a novel one-dimensional continuum model for twin branching, where twin spacing is continuously changed. Our approach is based on the energy minimization principle, wherein the total energy encompasses contributions from elastic strain energy and interfacial energy. Employing the finite element method, we effectively solve the associated weak form equations. Our results demonstrate quantitative agreement with Seiner et al. [3] across a wide range of physically relevant parameters. Furthermore, we extend our model to incorporate both viscous and rate-independent dissipation into the framework. Through the propagation of the A-MM interface, we investigate how the twin spacing, energies and branched microstructures are affected.

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