Finite-strain constitutive model for shape memory alloys formulated in the logarithmic strain space

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The unique mechanical properties of shape memory alloys (SMAs) have found applications in numerous engineering devices across different industries. Many of these applications inherently undergo large rotations and/or moderate or finite strains. Consequently, computational analysis of their mechanical response must be extended beyond the small-strain regime.

This contribution presents a finite-strain version of an established three-dimensional constitutive model for polycrystalline SMAs [1]. The original small-strain model, developed within the Generalized Standard Materials framework, was augmented to be more versatile in capturing the transformation kinetics. Then it was extended to the finite strains regime using the approach introduced in [2]: instead of modifying the constitutive core, the extended model was constructed via reinterpreting the inputs of the original small-strain model within the Lagrangian logarithmic (Hencky) strain space and via employing geometric pre- and post-processing to map between the objects in logarithmic strain space (e.g. Hencky strain, logarithmic stress) and those in the Lagrangian reference (e.g. right Cauchy–Green deformation tensor, nominal stress).

The main implementation challenge lies in algorithmizing the pre- and post-processing phases, with tensor spectral decomposition as the primary computational bottleneck. This was addressed by leveraging the vectorization capabilities of MATLAB software and the techniques introduced in [3]. The model was then implemented in finite element software to solve evolutionary boundary value problems. Material parameters were fitted to experimental data for two SMAs, and computational simulations of SMA components were conducted to demonstrate the model's performance and validate the implementation. The applied approach is highly flexible for incorporating also other phenomena, e.g., irreversibility associated with plasticity, into the model.

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