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Modeling Shape Memory Alloy Plane Truss Structures using the Finite Element Method

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ABSTRACT

The remarkable characteristics of shape memory alloys (SMA) have been responsible for the increasing interest in different applications varying from biomedical to aerospace industry. During the recovering process of a SMA component, large loads and/or displacements can be generated in a relatively short period of time making this component an interesting mechanical actuator. The thermomechanical behavior of SMA is related to phase transformations induced by stress and/or temperature variations. This article deals with the modeling and simulation of SMA plane truss structures using an anisothermal constitutive model with internal variables that includes three macroscopic phases in the formulation: two variants of martensite and an austenitic phase. A numerical procedure is developed based on the operator split technique associated with an iterative numerical scheme in order to deal with nonlinearities in the formulation. With this assumption, coupled governing equations are solved considering three uncoupled problems: thermal, thermo-elastic and phase transformation behaviors. The thermal problem comprises a one-dimensional conduction problem with surface convection. Finite element method is employed for spatial discretization. The thermo-elastic problem evaluates stress and displacement fields from temperature distribution, employing the nonlinear finite element method. Finally, the phase transformation problem determines the phase transformation fields considering the phase evolution in the process. Numerical simulations treats SMA plane truss structures subjected to thermomechanical loadings. The analysis considers results obtained for two models: uncoupled and coupled. The uncoupled model neglects the thermomechanical couplings, corresponding to the rigid body energy equation. The coupled model considers the latent heat associated with phase transformation as a source in the energy equation. Results show that the proposed model captures the general behavior of SMAs, allowing the description of adaptive trusses with large displacements. Moreover, they show the some situations where the thermomechanical coupling plays an important role in the description of SMA behavior.