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Numerical Modeling of Nonlinear Thermodynamics in SMA Wires

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In this talk I present a mathematical model designed to describe the thermodynamic behavior of shape memory alloy wires, as well as a computational technique to solve the resulting system of partial differential equations.

The material physics for such shape-changing materials may be modeled by a system of conservation equations based on a nonconvex free energy potential. To deal with this model, we first discretize the resulting system of equations implicitly in time, using a piecewise linear space-time Galerkin method to satisfy discrete conservation principles. This discretization results in a nonlinear, nonconvex root-finding problem for the time-evolved finite element expansion coefficients. To solve this system, we introduce a computational technique that combines a standard Newton-Krylov nonlinear solver with a viscosity-based continuation method.

We find that the proposed solution method allows the model to better handle dynamic applications where the temporally local behavior of solutions is desired, as compared with previous solution techniques that required the addition of large viscous effects to stabilize the nonlinear system. Moreover, computational experiments document that this combination of modeling and solution techniques appropriately predicts the thermally- and stress-induced material phase transformations, as well as the hysteretic behavior and production of latent heat associated with such materials.