Thermo-Viscoplasticity for Case Hardening Steels at Finite Deformations and Wide Temperature Ranges

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ABSTRACT

The aim of this work is the development of a thermodynamically consistent fully coupled thermo-viscoplastic material model for metals undergoing finite deformation and large temperature changes.

The deformation gradient is supposed to be decomposable into a thermal, an elastic, and a plastic part, where purely volumetric thermal expansion and isochoric plastic distortion is assumed. The model is based on a split of the free energy into a thermo-elastic and a plastic part. Where the first part is dependent on the elastic deformation gradient and the temperature, and the latter, covering non-linear cold-work hardening, shall only depend on the internal variables. Within this ansatz for the free energy and the kinematics, nonlinear temperature dependent effects are accounted for the elastic moduli, the thermal expansion, the heat capacity and the heat conductivity.

Based on an associative flow rule, strain rate-dependency of the current yield stress is realised using a temperature dependent nonlinear Perzyna-type viscoplastic model in combination with a von Mises yield function enhanced by non-linear thermal softening. The model and its parameters are fitted against experimental data for case hardening steel 16MnCr5 (1.7131).

We discuss the consistent linearisation of the proposed model and its implementation in a monolithic fully coupled finite element framework. Special care has been taken on the implementation of the incompressibility constraint on the plastic deformation gradient. Finally, we present results for selected boundary value problems demonstrating the performance of the model.

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