Phenomenological modeling of strain hardening, phase transformation and damage effects of TRIP-steels

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ABSTRACT

Metastable austenitic steels exhibit transformation induced plasticity (TRIP-effect) during mechanical loading due to martensite formation. This leads to an excellent ductility and a high strain hardening capability. Recent experiments of a specific highly alloyed TRIP-steel revealed two features, which will be addressed in the present paper by suitable modeling approaches: Firstly, an asymmetric strain hardening and a different martensite evolution behavior are observed comparing uni-axial tension and compression test results. Secondly, ductile damage mechanisms (void nucleation and growth) lead to the material's failure in a large temperature and strain rate range.

The asymmetric material behavior is modeled by taking into account the triaxiality of the stress state and the third invariant of stress deviator in the hardening evolution as well as in the transformation kinetics law. Starting point of the damage formulation is the effective stress concept known from the framework of continuum damage mechanics (see [1]). The porosity of the material is chosen as damage variable. As damage evolution, the model proposed by Rousselier is implemented [2]. In order to simplify the numerical treatment, a sequential evaluation of the undamaged material behavior and the damage evolution is proposed.

Furthermore, enhancements are incorporated into the damage model to avoid a spurious mesh dependency of FEM simulation results. An implicit gradient based enrichment method (see [3]) is applied to realize a non-local damage formulation. For the implementation into the commercial FEM-software ABAQUS, the analogy between the additional Helmholtz-type equation of implicit gradient enrichment and the already built-in heat conduction equation is used.

The final model is calibrated with help of experimental data and numerical studies: The macroscopic behavior of the TRIP-steel containing micro-voids is simulated by cell models for various stress triaxialities. A good calibration result is achieved. Results of convergence studies and numerical examples using the non-local damage model are also discussed.

REFERENCES

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