Gradient Crystal Plasticity Simulation of Large-Grain Thin-Sheet Metal

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ABSTRACT

Intrinsic size-dependent behavior of materials and inhomogeneous plastic flow on the micro-scale level are widely observed in experiments. Prediction of such a size-dependent response requires incorporation of atomistic slip systems, gradient description and length scale parameters into the conventional plasticity models. Furthermore, in the polycrystalline materials, existence of boundary layer subdividing adjacent grains plays an important role. The influence of grain boundaries on dislocation movement can be diverse, depending on e.g. the orientation angles of the adjacent grains.

In this study, a well-defined gradient crystal plasticity model [1] is employed to study the mechanical response and orientation gradient in a large-grain thin-sheet metal under uniaxial loading. The constitutive model is an extended description based on the microscopic force balance and is consistent with the thermodynamic laws. The free energy comprises two parts: a hyperelastic part in terms of compressible material and a part involving dislocation densities via Peach–Koehler forces conjugate to corresponding glide directions. A non-local plastic flow rule in the form of partial differential equation is introduced.

In terms of numerical solution, an implementation method which has been recently introduced in [2] is adopted. In this method, the proposed constitutive model is implemented in the FEM software ABAQUS via a user-defined element subroutine (UEL). The displacement components and the dislocation densities are chosen as nodal degrees of freedom (Global variable). Whereas, the nonlocal flow rule is applied to the Gauß integration points and solved to obtain the plastic flow in each slip system via the Newton-Raphson scheme (Local variable).

As a benchmark test, the model is applied to study the mechanical response and the orientation gradient of a multicrystal thin-sheet metal under uniaxial loading. The numerical results will be compared with the corresponding experimental measurements.

REFERENCES

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