Small strain crystal plasticity based on the infeasible primal-dual interior point method

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ABSTRACT

Single crystal plasticity, which plays a major role in the analysis of material anisotropy and texture evolution, treats each crystalline grain, having a distinct orientation, individually. The polycrystalline material response is obtained upon considering a structure consisting of various individual grains, often also considering interface effects at the grain boundaries. On the individual grain level, single crystal plasticity can be treated in the mathematical framework of multisurface plasticity, leading to a constrained optimization problem wherein multiple constraints are defined as yield criteria on the different slip systems. Different approaches have been established in this field, see, e.g., [2], [3]. In rate-independent models, the set of active slip systems in the grain is possibly nonunique and is identified in, e.g., an active set search. Rate dependent approaches are based on power-type creep laws which do not differentiate into active or inactive slip systems. However, the constitutive equations of these formulations are often very stiff and require a small time increment. Here, a new algorithm for the solution of the constrained optimization problem based on the infeasible primal-dual interior point method (IPDIPM), [1], involving slack variables is presented for the framework of small strain single crystal plasticity. The use of slack variables therein stabilizes the conventional method and allows for a temporary violation of the constraint during the optimization. The optimization is solved using a Lagrange functional, wherein the nonlinear system of equations resulting from the derivation of the Lagrange functional is linearized using taylor expansion and solved by a Newton Raphson scheme. All slip systems are considered simultaneously, omitting an iterative active set search. IPDIPM has been found to lead to very efficient algorithms and better convergence rates than barrier or penalty methods in the past. The stability of the algorithm can be especially beneficial in complex material models, such as a multiscale description of polycrystalline materials. Several numerical examples are presented, showing the performance of the developed algorithm based on academic slip system setups of only a few slip systems as well as face-centered-cubic crystals.

REFERENCES

