Nested surfaces plasticity using Prager's rule for cyclic hardening/softening: theory and numerical aspects

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ABSTRACT

There are several plasticity models for cyclic loading which allow three-dimensional simulations and that can be implemented into finite element codes. The best-known models are bounding surface models, nonlinear kinematic hardening models and multilayer (or nested surfaces) models. Usual bounding surface models do not fulfil the Masing rules describing the Bauschinger effect. Nonlinear kinematic hardening models are based on the Armstrong and Frederick rule, the addition of multiple back-stresses, and non-associative hardening. Multilayer models consist of several nested surfaces to describe hardening. The best-known model is the one from Mroz, which uses also a non-associative hardening rule, the implicit implementation implies some restrictions in the model [1], and does not describe well the nonproportional loading [2]. Furthermore, multiaxial loading predictions depend strongly on the arbitrary number of surfaces employed to discretize the stress-strain curve [2].

On the contrary, multilayer plasticity using Prager's translation rule is associative and fulfils Masing's rules for kinematic hardening. Furthermore, it is just classical plasticity in which the effective nonlinear kinematic hardening is computed with the aid of history surfaces, and that theory and computational algorithm are recovered as a particular case if linear hardening is prescribed. Multilayer plasticity has been shown to predict the apparent yield surface shape evolution for nonproportional loading, i.e. the typical egg-shape [3].

In this work, we formulate a theory for multilayer plasticity using Prager's rule including mixed hardening, and perform its fully implicit, consistently linearized, numerical implementation. The new formulation includes cyclic hardening/softening, and may be used in finite element simulations of nonproportional fatigue cases. Simulations of proportional and nonproportional experiments are performed and compared against experimental data. Finite element predictions are also shown to demonstrate the robustness of the algorithm and its application to general-purpose simulations. Further details may be found in Reference [4].

REFERENCES

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