THERMODYNAMICALLY BASED DIRECTIONAL DISTORTIONAL HARDENING IN PLASTICITY

HEIDI P. FEIGENBAUM* AND YANNIS F. DAFALIAS*†

* Department of Civil and Environmental Engineering
University of California at Davis
Davis, California, 95616 USA

† Department of Mechanics
National Technical University of Athens
Zogrphou, 15780, Hellas
jfdafalias@ucdavis.edu

It has long been observed that plastic deformations induce anisotropy in initially isotropic materials, which is reflected through a translation of the yield surface (kinematic hardening) and a distortion of its initial shape in stress space (distortional hardening). Experiments on various metals, such as those by Phillips et al. [1] and Wu and Yeh [2], have shown that the distortion of the yield surface is characterized by a region of high curvature developed along the direction of loading and a region of flattening on the opposite side. This type of response will be called directional distortional hardening.

The present paper introduces a complete theory for metal plasticity that includes the development of kinematic and directional distortional hardening, supplemented by the classical isotropic hardening. Starting from an isotropic von Mises yield surface, the isotropic and kinematic hardenings will be modeled by evolution laws for the yield surface size and the back-stress tensor, respectively, while the distortional hardening will be modeled by an evolving fourth order tensor, an idea first proposed by Baltov and Sawczuk [3]. The directionality of the distortional hardening is obtained through a scalar multiplier of this fourth order tensor, defined in terms of the trace of the product of the effective stress tensor direction and the back-stress tensor.

What really sets apart this model from several other models developed in the past along similar lines, is that the hardening rules for all internal variables, including the cardinally important fourth order tensor, are derived strictly on the basis of sufficient conditions for the satisfaction of the second law of thermodynamics, in conjunction with a few simple and plausible assumptions about energy storage in the material. This leads to non-linear evanescent-memory type evolution laws for all internal variables, the fourth order tensor included, along the lines of a recent presentation by Dafalias et al. [4] where, however, the all important directionality of distortional hardening was not considered. The model needs only a few constants for calibration, and its ability to fit experimental data on distorted yield surfaces is demonstrated.

References

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Keywords: plasticity, distortional hardening