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Biaxial ratchetting with novel variations of kinematic hardening

Yannis F. Dafalias [a,b], Heidi P. Feigenbaum [c,*]

[a] Department of Civil and Environmental Engineering, University of California, Davis, CA 95616, USA
[b] Department of Mechanics, National Technical University of Athens, Zographou 15780, Hellas
[c] Department of Mechanical Engineering, Northern Arizona University, Flagstaff, AZ 86011, USA

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ABSTRACT

Kinematic hardening and the associated concept of back-stress and its evolution are fundamental constitutive ingredients of classical plasticity theory used to simulate the inelastic material response under stress reversals. Cyclic plasticity addresses such response under a sequence of repeated stress reversals, which results in plastic strain accumulation, called ratchetting. Biaxial ratchetting occurs whenever the material is loaded in two directions although typically the cyclic loading is only in one direction. The realistic description of the material response during cyclic loading depends strongly on the kind of kinematic hardening used.

This paper investigates the performance of some existing and novel kinematic hardening rules in the prediction of ratchetting. The multiplicative AF model by Dafalias et al. (2008a,b), which was originally applied to the simulation of uniaxial ratchetting, will be used here to simulate also biaxial ratchetting and will be compared with a model using the concept of a hardening stress threshold. The suggestion of Delobelle et al. (1995) to combine the Armstrong/Frederick and Burlet and Cailletaud (1986) kinematic hardening rules is incorporated in the aforementioned model and used to obtain improved simulations of biaxial ratchetting. After showing a deficiency of the foregoing suggestion which results in the possibility for the back-stress to cross it's bounding surface and induce a negative plastic modulus, a variation is proposed void of the foregoing deficiency, which is successfully tested in the simulation of multiple biaxial ratchetting experimental results on carbon steel 1026.

1. Introduction

Kinematic hardening and the associated concept of back-stress and its evolution are fundamental constitutive ingredients of classical plasticity theory used to simulate the inelastic material response under stress reversals. Cyclic plasticity addresses such response under a sequence of repeated stress reversals and the ensuing technologically important phenomenon of plastic strain accumulation, called ratchetting. Biaxial ratchetting is the accumulation of plastic strains due to loading in two directions. Typically biaxial ratchetting occurs when the material is pre-loaded in one direction and then cyclically loaded in another direction. Within this constitutive framework, the success of a model to realistically describe the material response in cyclic plasticity depends on the kind of kinematic hardening used.

The literature on kinematic hardening is vast and any attempt to cover it in this article is bound to be not complete. Nevertheless, one can at least identify some important building blocks starting with the first proposition of a linear kinematic hardening rule by Ishlinskii (1954) and Prager (1949), referred to as Prager linear kinematic hardening. The linear kinematic

* Corresponding author. Tel.: +1 925 523 5326.
E-mail addresses: jfdafalias@ucdavis.edu (Y.F. Dafalias), heidi.feigenbaum@nau.edu, hf38@nau.edu (H.P. Feigenbaum).

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