EXTENDED NOIHKH MODEL USAGE FOR CYCLIC PLASTICITY OF METALS

Ladislav Écsi*

In this paper a generalized NoIHKH material model for the cyclic plasticity of metals is presented. The model is an extension of the original NoIHKH model and uses an associative J2 plasticity material model with combined isotropic and kinematic hardening. In the paper is briefly outlined the original and extended material model mathematical formulation, their numerical implementation, and finally the models behavior is compared on a numerical example.

Key words : *finite element method (FEM), cyclic plasticity of metals, associative J2 plasticity with combined isotropic and kinematic hardening*

1. Introduction

At the end of 1970s several models were developed to model a material behavior during cyclic loading. One of them is the original NoIHKH model [11] utilizing the nonlinear combined isotropic and kinematic hardening. The rule was introduced in the simple form by Amstrong and Frederick [1] in 1966 and has been extensively used by Chaboche [3]–[6], [12], [23] since 1976 to build different models to describe the cyclic visco-plasticity and cyclic plasticity. The tension curve predicted by this model describes the nonlinear behavior in tension and the Bauschinger effect along a reverse loading. Over time, innumerous other, more complex models were proposed, accounting for such effects as transient or steady state cyclic response, non-proportional hardening, memory of maximal prestress, shakedown, ratcheting, etc. Some of the most significant of them include the multisurface hardening model for monotonic and cyclic response of metals proposed by Z. Mroz [14]–[21], [27], the kinematic hardening rule with critical state of dynamic recovery proposed by Nobutada Ohno [9], [10], [26], [28], the kinematic hardening rule for biaxial ratcheting devised by H. Ishikawa and K. Sasaki [7], [8]. A general and more comprehensive overview of the aforementioned models is presented in [11], [12] with some most recent developments in [22].

The majority of the models for cyclic plasticity calculate the back stress increment as a product of a plastic strain rate tensor and a scalar cyclic material modulus. Referring to the generalized Hook's law, it is well known that the stress tensor is not a product of the strain tensor and a scalar, but a fourth order material modulus, and thus all components of the Cauchy stress tensor increment, $\Delta\sigma_{\mathrm{xx}}$, $\Delta\sigma_{\mathrm{yy}}$, $\Delta\sigma_{\mathrm{zz}}$, taking part in the volume change of an infinitely small element of a body through the Poisson ratio, are directly interconnected with all components of the strain tensor increment $\Delta\varepsilon_{\mathrm{xx}}$, $\Delta\varepsilon_{\mathrm{yy}}$, $\Delta\varepsilon_{\mathrm{zz}}$ causing the volume change increment. Our aim in this work is to introduce a generalized cyclic material modulus for back stress, which will take into account the aforementioned interconnections between the

* L. Écsi, Department of Strength of Materials, Slovak University of Technology in Bratislava, Slovak Republic