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Constitutive modeling of temperature and strain rate dependent elastoplastic hardening materials using a corotational rate associated with the plastic deformation

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ABSTRACT

In this paper, a constitutive model with a temperature and strain rate dependent flow stress (Bergstrom hardening rule) and modified Armstrong–Frederick kinematic evolution equation for elastoplastic hardening materials is introduced. Based on the multiplicative decomposition of the deformation gradient,new kinematic relations for the elastic and plastic left stretch tensors as well as the plastic deformation-dependent spin tensor are proposed. Also, a closed-form solution has been obtained for the elastic and plastic left stretch tensors for the simple shear problem.To evaluate model validity, results are compared with known experimental data for SUS 304 stainless steel, which shows a good agreement with the results of the proposed theoretical model.Finally, the stress-deformation curve, as predicted by the model, is plotted for the simple shear problem at room and elevated temperatures using the same material properties for AA5754-O aluminium alloy.

1. Introduction

The analysis of elastic–plastic hardening materials under finite deformation are based on three important factors; the kinematic decomposition,corotational rate and constitutive equations in elastic and plastic regions.

In small deformation analysis of elastic–plastic materials, the strain tensor is decomposed additively into elastic and plastic parts. However, under finite deformations this decomposition is no longer valid (Khan and Huang, 1995). Thus, in the kinematic analysis of finite deformation elastic–plastic materials, other types of additive decompositions as well as multiplicative decompositions are used.The most common multiplicative method is the decomposition of the deformation gradient tensor which has been used by Lee and other researchers (Lee, 1969; Dafalias, 1987; Lubarda, 1999; Arghavani et al., 2010; Shim and Mohr, in press). The decomposition of the deformation gradient tensor has also been presented in other contexts, and other multiplicative decompositions have been introduced (Schieck and Stumpf, 1993; Lubarda, 1999; Gurtin and Anand, 2005; Metzger and Dubey, 1987). Recently, Arghavani et al. (2010), based on this decomposition, have presented a Hencky-based phenomenological finite strain kinematic hardening, non-associated constitutive model. They have applied the developed constitutive model to shape memory alloys and have proposed a well-defined, nonsingular definition for model variables. Ayoub et al. (2010) have improved the method developed by Boyce et al. (2000), in which they use deformation gradient decomposition to describe the mechanical behavior of high density polyethylene (HDPE). This model involves two parallel elements: a visco-hyperelastic network resistance acting in parallel with a viscoelastic and viscoplastic intermolecular resistance.

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