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A finite strain kinematic hardening constitutive model based on Hencky strain: General framework, solution algorithm and application to shape memory alloys

J. Arghavani [a,1], F. Auricchio [b,c,d], R. Naghdabadi [a,e,*]

[a] Department of Mechanical Engineering, Sharif University of Technology, 11155-9567 Tehran, Iran
[b] Dipartimento di Meccanica Strutturale, Università degli Studi di Pavia, Pavia, Italy
[c] Center for Advanced Numerical Simulation (CeSNA), IUSS, Pavia, Italy
[d] European Centre for Training and Research in Earthquake Engineering (EUCENTRE), Pavia, Italy
[e] Institute for Nano-Science and Technology, Sharif University of Technology, 11155-9567 Tehran, Iran

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ABSTRACT

The logarithmic or Hencky strain measure is a favored measure of strain due to its remarkable properties in large deformation problems. Compared with other strain measures, e.g., the commonly used Green–Lagrange measure, logarithmic strain is a more physical measure of strain. In this paper, we present a Hencky-based phenomenological finite strain kinematic hardening, non-associated constitutive model, developed within the framework of irreversible thermodynamics with internal variables. The derivation is based on the multiplicative decomposition of the deformation gradient into elastic and inelastic parts, and on the use of the isotropic property of the Helmholtz strain energy function. We also use the fact that the corotational rate of the Eulerian Hencky strain associated with the so-called logarithmic spin is equal to the strain rate tensor (symmetric part of the velocity gradient tensor). Satisfying the second law of thermodynamics in the Clausius–Duhem inequality form, we derive a thermodynamically-consistent constitutive model in a Lagrangian form. In comparison with the available finite strain models in which the unsymmetric Mandel stress appears in the equations, the proposed constitutive model includes only symmetric variables. Introducing a logarithmic mapping, we also present an appropriate form of the proposed constitutive equations in the time-discrete frame. We then apply the developed constitutive model to shape memory alloys and propose a well-defined, non-singular definition for model variables. In addition, we present a nucleation-completion condition in constructing the solution algorithm. We finally solve several boundary value problems to demonstrate the proposed model features as well as the numerical counterpart capabilities.

1. Introduction

In recent years much attention has been devoted to the development of constitutive laws for large deformations of solids. The logarithmic strain, sometimes referred to as true or natural strain, introduced by Hencky (1928) and also called Hencky

* Corresponding author at: Department of Mechanical Engineering, Sharif University of Technology, 11155-9567 Tehran, Iran. Tel.: +98 21 6616 5546; fax: +98 21 6600 0021.
E-mail address: naghdabd@sharif.edu (R. Naghdabadi).
[1] Currently visiting Ph. D. student, Dipartimento di Meccanica Strutturale, Universit'a degli Studi di Pavia, Italy.

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