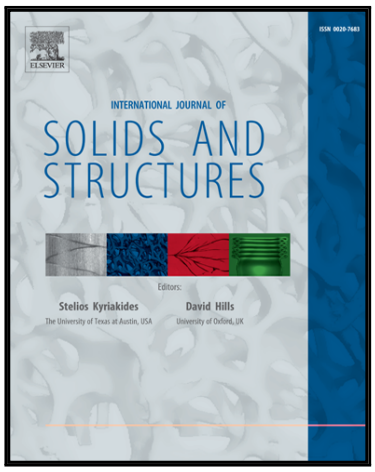

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Theoretical and numerical modeling of dense and porous shape memory alloys accounting for coupling effects of plasticity and transformation

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Abstract

The present work develops three-dimensional phenomenological constitutive models for dense and porous shape memory alloys (SMAs). The models are extensions of a recent work and considers pressure dependent behavior for porous SMAs as well as the coupling effects of transformation and plasticity for both dense and porous SMAs. In contrast to dense SMAs, a considerable plastic strain accumulates in porous SMAs even during phase transformation. Therefore, an effective solution algorithm for simultaneous evolution of transformation and plastic strain is presented via replacement of the classical Kuhn-Tucker inequality conditions by the so-called Fischer-Burmeister complementarity function. Numerical predictions are compared with experimental results and a comprehensive study is performed on the material parameters regarding coupling effects and pressure dependency. Moreover, we implement the model using corotational formulation and perform finite element analysis of a porous SMA spring actuator, and a tube under non-proportional loading to assess the reliability of the proposed model for large rotations and general multiaxial loadings.

Keywords: Shape memory alloys, Porous materials, Pressure dependency, Phase transformation, Plasticity, Fischer-Burmeister function

1. Introduction

Shape memory alloys (SMAs) have unique features (shape memory effect and pseudoelasticity), which make them good candidates in aerospace and biomedical applications. In addition to dense SMAs, porous SMAs have drawn increasing attention in the past years. Benefiting from the characteristics of porous metals, porous SMAs can be used as a light-weight or graded structure in biomedical implants, and energy absorbers (Qidwai et al., 2001; Zhao et al., 2006; Lefebvre et al., 2008; Bansiddhi et al., 2008).

An important phenomenon related to the thermomechanical behavior of shape memory alloys is plasticity. Pseudo-elasticity and shape memory effect of SMAs are due to martensitic phase transformation under

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