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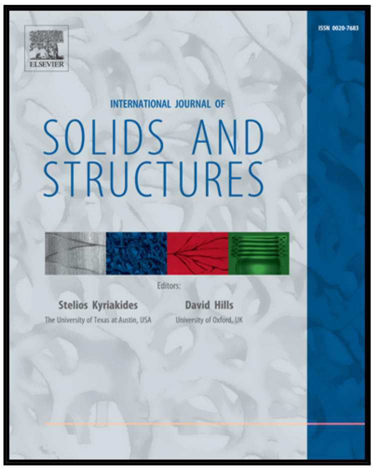

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Experimental characterization and continuum modeling of inelasticity in filled rubber-like materials

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Abstract

Filled rubber-like materials are important engineering materials, and they are widely used in aerospace, automotive, and other industries. However, their nonlinear, inelastic, and rate-dependent constitutive behavior is not fully understood and modeled with varying degrees of success. Much of the previous literature has focused on either capturing quasi-static stress-softening behavior or rate-dependent viscous effects, but generally not both concurrently. In this work, we develop a thermodynamically consistent constitutive model which accounts for both of those phenomena concurrently. A set of comprehensive mechanical tensile tests were conducted on the filled rubber Viton. The constitutive model was then calibrated to the experimental data, and numerically implemented into the finite element package Abaqus by writing a user material subroutine UMAT. The constitutive model was validated by comparing a numerical simulation prediction with an inhomogeneous deformation experiment.

Keywords: Rubbers; Time-dependent; Viscoelastic; Nonlinear; Inelastic.

1 Introduction

The crosslinked polymer matrix of a rubber typically incorporates stiff filler particles of carbon black and silica in order to enhance its mechanical performance, and these materials are called filled rubber-like materials. Filled rubbers are widely used in industrial and consumer applications (Clark, 1981; Snowdon, 1968; Chandrasekaran, 2009) ranging from tires, shock absorbers, and O-ring seals. The mechanical behavior of such materials often determines its limitations in applications. For example, the catastrophic loss of the Challenger space shuttle in 1986 was caused in part by an O-ring made of Viton (Rogers Commission, 1986), a filled rubber-like material. Accidents such as

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