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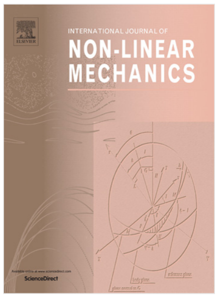

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Preisach description for solids with frictional cracks

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Abstract

The observation of a hysteretic stress-strain relationship is widespread for a large class of solids, such as rocks and other geomaterials, concretes, bones, etc. A common feature that unifies these materials is the presence of internal mechanical contacts in their structure, which can either be natural, or appear as the result of damage or fatigue in consolidated materials with an originally non-hysteretic mechanical response. Even though a number of physical mechanisms can be identified to account for mechanical hysteresis, at moderate and high strains, when typical internal contact displacements largely exceed the atomic size, a friction-based mechanism becomes of primary importance. As an alternative for a physics-based description, phenomenological approaches, ignoring the physical nature of hysteresis, are often used in numerical simulations. In this paper, we intend to bridge the physical mechanism of friction-based hysteresis with the phenomenological Preisach formalism, and derive the Preisach density in a compact analytical form for a model system that represents an elastic continuum with a large number of diversely oriented frictional cracks. We validate the physical crack friction model and its phenomenological Preisach counterpart with experimental data for Fontainebleau sandstone. The new formulations and the results could be of interest for materials scientists dealing with systems that show hysteretic elasticity and/or distributed damage, geomaterials or construction materials.

Keywords: mechanical hysteresis; dry friction; solids with cracks; Preisach model

1. Introduction

There exists a large class of materials (rocks, minerals, construction materials, composites, ceramics, polycrystalline metals, martensites) exhibiting hysteresis in their stress-strain response [1,2,38]. A common feature that unifies these materials is the presence of internal mechanical contacts in their structure, which can either be natural, or appear as the result of damage or fatigue in consolidated materials with an originally non-hysteretic mechanical response. In the simplest case, it means that for loading and subsequent unloading of a sample the loading and unloading curves do not coincide but form a usual closed "hysteresis loop". The execution of a loading protocol