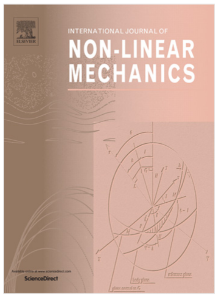

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Phase Field Modeling of Fracture in Anisotropic Brittle Solids

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Abstract

A phase field model of fracture that accounts for *anisotropic material behavior at small and large deformations* is outlined within this work. Most existing fracture phase field models assume crack evolution within isotropic solids, which is not a meaningful assumption for many natural as well as engineered materials that exhibit orientation-dependent behavior. The incorporation of anisotropy into fracture phase field models is for example necessary to properly describe the typical sawtooth crack patterns in strongly anisotropic materials. In the present contribution, anisotropy is incorporated in fracture phase field models in several ways: (i) Within a pure geometrical approach, the crack surface density function is adopted by a rigorous application of the *theory of tensor invariants* leading to the definition of structural tensors of second and fourth order. In this work we employ structural tensors to describe transverse isotropy, orthotropy and cubic anisotropy. Latter makes the incorporation of second gradients of the crack phase field necessary, which is treated within the finite element context by a nonconforming Morley triangle. Practically, such a geometric approach manifests itself in the definition of anisotropic effective fracture length scales. (ii) By use of structural tensors, energetic and stress-like failure criteria are modified to account for inherent anisotropies. These failure criteria influence the crack driving force, which enters the crack phase field evolution equation and allows to set up a modular structure. We demonstrate the performance of the proposed anisotropic fracture phase field model by means of representative numerical examples at small and large deformations.

Keywords: brittle fracture, anisotropic crack propagation, phase field modeling, finite elements

1. Introduction

Fracture is the fragmentation of a solid due to the evolution of one or more cracks. The development of numerical strategies that predict failure mechanisms due to crack initiation and propagation is an intriguingly challenging task, and plays an extremely important role in various engineering applications. From a computational point of view, the tracking of sharp crack surfaces provides substantial difficulties and is often restricted to simple crack topologies. This difficulty can be overcome by recently developed phase field approaches to fracture, which regularize sharp crack discontinuities within a pure continuum formulation. This geometrically motivated diffusive crack modeling allows the resolution of complex failure patterns. Phase field modeling of fracture has become a topic of focused research in recent years to describe crack patterns in various kinds of solid materials. To this end, three basic approaches to the regularized modeling of Griffith-type *brittle fracture* in elastic solids may be distinguished: (i) The phase field approach by Karma et al. [32] and Hakim & Karma [26] applies a Ginzburg-Landau-type evolution of an unconstrained crack phase field, using a non-convex degradation function that separates unbroken and broken states. However it does not explicitely account for an irreversibility constraint on the crack evolution. (ii) The fundamental approach of Francfort & Marigo [20] and Bourdin et al. [11, 12] adopts the variational structure and Γ-convergent regularization of image segmentation developed by Mumford & Shah [48] and Ambrosio & Tortorelli [5] for the analysis of finite increments in

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