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Modeling and simulation of quasi-brittle failure with continuous anisotropic stress-based gradient-enhanced damage models

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Abstract

Two anisotropic stress-based gradient-enhanced damage models are proposed to address the issue of spurious damage growth typical of continuous standard gradient-enhanced damage models. Both models are based on a decreasing interaction length upon decreasing stresses and do not require additional model parameters or extra degrees of freedom when compared to standard gradient-enhanced models. It is observed that with the proposed models damage spreading is significantly reduced due to the occurrence of non-physical oscillations in the nonlocal strain field near the strain localization band. Model improvements to eliminate these strain oscillations upon vanishing length scale values are proposed. The capability of the models and their patched versions to correctly simulate damage initiation and propagation is investigated by means of mode-I failure, shear band and four-point bending tests.

Keywords: gradient-enhanced damage, anisotropic damage, quasi-brittle failure, transient length scale

1. Introduction

Using a nonlocal model for modeling damage in quasi-brittle materials, either in its original integral form [1] or its differential, gradient-enhanced form [2], solves the well-known mesh-dependency issue of local damage models where strains tend to localize in the smallest element of the discretization [3]. However, it has been reported that these nonlocal models may introduce other issues such as an initiation of damage at a wrong location and the artificial spreading of damage [4, 5]. In this paper, we present a class of gradient-enhanced damage models that addresses these unwanted phenomena by employing an anisotropic, stress-dependent nonlocal interaction kernel.

The key feature of the proposed models lies in the use of a transient length scale and thus a decreasing nonlocal activity when stresses decrease. The idea of using a transient length scale or, equivalently, a transient gradient activity parameter in gradient-enhanced damage models was already proposed by Geers et al. [4] who employed a strain-based formulation requiring an additional set of degrees of freedom compared to the standard model (their model was reformulated

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