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Robust numerical implementation of non-standard phase-field damage models for failure in solids

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Abstract

Recently several non-standard phase-field models different from the standard one for brittle fracture (Bourdin et al., 2000, 2008; Miehe et al., 2010a) have been proposed for the modeling of damage and fracture in solids. On the one hand, linear elastic behavior before the onset of damage and even cohesive cracking induced quasi-brittle failure can be considered by such non-standard phase-field models. On the other hand, they present great challenges to the numerical implementation since the damage boundedness is no longer automatically fulfilled. In this work, the numerical implementation of the unified phase-field damage model (Wu, 2017, 2018) is addressed, though it also applies to the standard and other non-standard ones. In particular, an iterative alternate minimization (AM) algorithm enhanced with path-following strategies is presented. The phase-field or damage sub-problem is solved by the bound-constrained optimization solver in which the boundedness and irreversibility conditions of the crack phase-field are exactly enforced. Moreover, material softening induced snap-backs typically for localized failure in solids can also be effectively dealt with. The equilibrium paths in terms of the fracture surface and the indirect displacement (e.g., the crack mouth opening or sliding displacement) are discussed in the context of the AM algorithm. The AM algorithm with the indirect displacement control is advocated, since both prescribed external forces and displacements can be naturally dealt with, which is more versatile than the one with the fracture surface control applicable only for prescribed displacements. Representative examples of benchmark tests show that the AM algorithm enhanced with the indirect displacement control is extremely robust even for large increment sizes. The insensitivity of the unified phase-field damage model to the incorporated length scale and mesh size is also confirmed.

Keywords:
Phase-field theory; gradient-damage model; alternate minimization; arc-length method; quasi-brittle failure.

1. Introduction

Cracking induced localized failure in solids is usually regarded as prognostics of catastrophic collapse of engineering structures. Therefore, it is of vital importance to predict the occurrence of localized failure and quantify its effects

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