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A length scale insensitive phase-field damage model for brittle fracture

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Abstract

Being able to model complex nucleation, propagation, branching and merging of cracks in solids within a unified framework, the classical phase-field models for brittle fracture fail in predicting length scale independent global responses for a solid lacking elastic singularities (e.g., corners, notches, etc.). Motivated from Barenblatt's approximation of Griffith's brittle fracture with a vanishing Irwin's internal length, this paper extends our recent work in quasi-brittle failure (Wu, 2017, 2018a) and presents for the first time a length scale insensitive phase-field damage model for brittle fracture. More specifically, with a set of optimal characteristic functions, a phase-field regularized cohesive zone model (CZM) with linear softening law is addressed and applied to brittle fracture. Both the failure strength and the traction – separation law are independent of the incorporated length scale parameter. Compared to other phase-field models and CZM based discontinuous approaches for brittle fracture, the proposed phase-field regularized CZM is of several merits. On the one hand, being theoretically equivalent to Barenblatt's CZM (at least in the 1-D case), it needs neither the explicit crack representation/tracking nor the elastic penalty stiffness which both are necessary but cumbersome for discontinuous approaches. On the other hand, it gives length scale independent global responses for problems with or without elastic singularities while preserving the expected $\varGamma$-convergence property of phase-field models. Representative numerical examples of several well-known benchmark tests support the above conclusions, validating its capability of modeling both mode-I and mixed-mode brittle fracture.

Keywords:
Phase-field theory; length scale; brittle fracture; damage; cohesive zone model.

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1. Introduction

Fracture is one of the most commonly encountered failure modes of engineering materials and structures. The prevention of cracking induced failure is, therefore, a major concern in engineering designs. Similarly to many other physical phenomena, computational modeling of crack initiation and propagation in solids constitutes an indispensable tool not only to predict the failure of cracked structures but also to shed insights into the failure mechanism of many materials such as concrete, rock, ceramic, metals, biological soft tissues etc.

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