Accepted Manuscript

Phase-field modeling of brittle fracture using an efficient virtual element scheme

Fadi Aldakheel, Blaž Hudobivnik, Ali Hussein, Peter Wriggers

PII: S0045-7825(18)30339-6
DOI: https://doi.org/10.1016/j.cma.2018.07.008
Reference: CMA 11980

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 2 March 2018
Revised date : 3 July 2018
Accepted date : 4 July 2018

Phase-Field Modeling of Brittle Fracture Using an Efficient Virtual Element Scheme

Fadi Aldakheel*, Blaž Hudobivnik, Ali Hussein, Peter Wriggers*

Institute of Continuum Mechanics, Leibniz Universität Hannover, Appelstrasse 11, 30167 Hannover, Germany

Abstract

This work addresses an efficient low order *virtual element method* (VEM) for the phase-field modeling of isotropic brittle fracture. Virtual elements were introduced in the last decade and applied to various problems in solid mechanics. The phase-field approach regularizes sharp crack surfaces within a pure continuum setting by a specific gradient damage modeling with constitutive terms rooted in fracture mechanics, see Miehe et al. [1, 2]. In the presented contribution, we propose a rigorous variational-based framework for the phase-field modeling of brittle fracture in elastic solids undergoing small strains. The key goal here, is the extension towards the recently developed virtual element formulation due to the flexible choice of nodes number in an element which can be changed easily during the simulation process, as outlined in Wriggers et al. [3, 4]. To this end, the *potential density* is formulated in terms of suitable polynomial functions, instead of computing the unknown shape functions for complicated element geometries, e.g. arbitrary convex or concave polygonal elements. An important aspect of this work is the introduction of an incremental minimization principle, with a novel construction of the *stabilization density* for the coupled multi-field problem. On the computational side, a robust and efficient *monolithic scheme* is employed using the software tool AceFEM program in the numerical implementation to compute the unknowns (displacement and crack phase-field), see Korelc and Wriggers [5]. The performance of the formulation is underlined by means of representative examples.

Keywords: Virtual Element Method (VEM); Phase-Field Modeling; Brittle Fracture; Stabilization.

1. Introduction

The finite element method (FEM) is a well established tool for solving a wide range of boundary value problems in science and engineering, see e.g. Bathe [6], Zienkiewicz et al. [7] and Wriggers [8]. However in recent years different methods like the isogeometric analysis outlined in Hughes et al. [9, 10] and the virtual element method proposed in Beirão Da Veiga et al. [11] were introduced as tools that bring some new features to the numerical solution of problems in solid mechanics. The virtual element method is a generalization of the finite element method, which has inspired from modern *mimetic finite difference schemes*, rooted in the pioneering work of Brezzi et al. [12]. It has proven to be a competitive discretization scheme for meshes with irregularly shaped elements that can even become non-convex. Furthermore, VEM allows exploration of features such as flexibility with regard to mesh generation and choice of element shapes, e.g. use very general polygonal and polyhedral meshes. In this regard, a stabilization procedure is required in the virtual element method, as described in Cangiani et al. [13] for linear Poisson problems. So far applications of virtual elements have been devoted to linear elastic deformations in Gain et al. [14] and Artioli et al. [15], contact problems in Wriggers et al. [3], 3D finite elasto-plastic deformations in Hudobivnik et al. [16], anisotropic materials at finite strains in Wriggers et al. [17, 18], 2D magnetostatic problems in Beirão Da Veiga et al. [19], inelastic solids in Taylor and Artioli [20] and hyperelastic materials at finite deformations in Chi et al. [21] and

*Corresponding authors.
Email addresses: aldakheel@ikm.uni-hannover.de (Fadi Aldakheel), wriggers@ikm.uni-hannover.de (Peter Wriggers)