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Recent advancements on the phase field approach to brittle fracture for heterogeneous materials and structures

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Abstract

Recent advancements on the variational approach to fracture for the prediction of complex crack patterns in heterogeneous materials and composite structures is herein proposed, as a result of the frontier research activities undertaken in the FP7-ERC Starting Grant project CA2PVM which focuses on the development of computational methods for the durability and the reliability assessment of photovoltaic laminates. From the methodological viewpoint, the phase field approach to describe the propagation of brittle fracture in the bulk has been coupled for the very first time with the cohesive zone model to depict interface crack growth events, for 2D isotropic and anisotropic constitutive laws, and also for 3D finite elasticity. After a summary of the key aspects underlying the theoretical formulation and the finite element implementation using a monolithic fully implicit solution scheme, an overview of the main technological applications involving layered shells, interface mechanical problems and polycrystalline materials is provided. The examples are selected to show the capability of the proposed approach to investigate complex phenomena such as crack deflection vs. crack penetration at an interface, intergranular vs. transgranular crack growth in polycrystals, and interlayer vs. translayer failure in laminates.

Keywords: Phase field model of fracture, Cohesive zone model, Solid shell, Heterogeneous materials, Nonlinear finite element method

Introduction

The phenomenology and modelling of brittle fracture is a well established topic in the area of fracture mechanics. In the last decades, many computational models have been developed in order to predict the strength and the crack path in brittle materials. Techniques such as the extended finite element method (XFEM) [1, 2], finite fracture mechanics (FFM) [3] and the embedded finite element method (EFEM) [4] belong to this class of approaches. In parallel, methods to simulate quasi-brittle and interface fracture adopting the cohesive zone model (CZM) have been proposed to simulate cohesive fracture typical of elastoplastic materials or interfaces. These computational models generally suffer from some drawbacks due to the complexity in tracing the evolution of the crack path. On the one side in XFEM and EFEM, a splitting algorithm should be defined for the element crossed by the crack or containing the crack tip. This leads to crack topology problems when

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