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Phase-field description of brittle fracture in plates and shells

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Abstract

We present an approach for phase-field modeling of fracture in thin structures like plates and shells, where the kinematics is defined by midsurface variables. Accordingly, the phase field is defined as a two-dimensional field on the midsurface of the structure. In this work, we consider brittle fracture and a Kirchhoff-Love shell model for structural analysis. We show that, for a correct description of fracture, the variation of strains through the shell thickness has to be considered and the split into tensile and compressive elastic energy components, needed to prevent cracking in compression, has to be carried out at various points through the thickness, which prohibits the typical separation of the elastic energy into membrane and bending terms. For numerical analysis, we employ isogeometric discretizations and a rotation-free Kirchhoff-Love shell formulation. In several numerical examples we show the applicability of the approach and detailed comparisons with 3D solid simulations confirm its accuracy and efficiency.

Keywords: Phase field; Fracture; Shell; Plate; Kirchhoff-Love; Isogeometric analysis

1. Introduction

The prediction of fracture in thin structural members is a crucial aspect for the safety assessment of engineering structures in various industries, e.g., in the automotive (car bodies), aerospace (aircraft fuselages), and marine (ship hulls, tanks, and vessels) industries, or in the field of renewable energies (wind turbines). A special challenge in such applications is the correct combination of fracture models, which are mostly derived within a solid mechanics framework, with structural models like plates and shells, which feature a special load-carrying behavior and are based on dimensionally-reduced kinematics.

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