EFFICIENT SIMULATION OF CRACK PROPAGATION IN COMPLEX GEOMETRIES USING A PHASE-FIELD MODEL AND THE FINITE CELL METHOD

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ABSTRACT

Phase-field models for fracture are based on a diffused approximation of the crack using a scalar field variable, which altogether avoids the modeling of discontinuities. Although widely used and extended to a broad range of applications, phase-field simulations of large-scale scenarios featuring complex geometries and crack patterns are still a challenging task. In this contribution, a numerical framework is proposed which combines a phase-field model for brittle fracture with an adaptive refinement technique and an embedded domain approach to an efficient tool for the simulation of complex, 3-dimensional crack scenarios.

In the phase-field approach, the regularization of the sharp crack is based on a length-scale parameter which governs the extent of diffusion and determines the numerical width of the crack. For small length-scale parameters, a very fine mesh is needed at least in the vicinity of the crack to fully resolve the resulting crack profile. As this can quickly become expensive, Nagaraja et al. [3] combined multi-level hp-refinement [4] and a phase-field approach for brittle fracture in two dimensions to allow for a locally refined mesh which dynamically adapts to the crack path. In a second step, the Finite Cell Method (FCM) [1] was successfully integrated into the model to enable the efficient simulation of complex geometries. The numerical framework was extended to 3D and validated in terms of crack propagation and nucleation in homogeneous and isotropic material based on a newly suggested benchmark problem [2].

To demonstrate the potential of the proposed numerical framework, two application examples of complex and heterogeneous geometries based on CT-scan data are considered. In a first application, compression fracture of human vertebrae is simulated numerically and validity of the phase-field model is discussed in a comparison with experimental data. In a second part, uniaxial compression tests on geological core samples are simulated. Both examples demonstrate the advantages of combining a phase-field model with the FCM and multi-level hp-refinement for the efficient simulation of complex crack propagation phenomena.

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