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FRACTURE WITH PHASE-FIELD MODELS: DISCRETIZATION, ACCELERATION, APPLICATION

S. KOLLMANNSBERGER*, L. HUG*, L. HERRMANN*, A. DANESHYAR*, P. KOPP*, O. OZTOPRAK*, K. THURO+, Y. SCHAPIRA†, L. RADKE†, A. DÜSTER† AND E. RANK*

* Chair of Computational Modeling and Simulation, Technical University of Munich,
Arcisstr. 21, 80333 Munich, Germany
stefan.kollmannsberger@tum.de

+ Chair of Engineering Geology, Technical University of Munich,
Arcisstr. 21, 80333 Munich, Germany

† Institute for Ship Structural Design and Analysis, Hamburg University of Technology,
Am Schwarzenberg Campus 4 c, 21073 Hamburg, Germany

ABSTRACT

This presentation will provide an overview and an evaluation of modern discretizational techniques of phase-field methods for fracture. To this end, this talk will open with a motivating example of a geometrically very complex 3D fracture of a core rock sample (see Figure 1). It is well known that such computations are challenging. This is mainly because:

- the phase-field regularization of the sharp crack is based on a length-scale parameter that requires very fine computational meshes,
- domains of interest may possess very complex topologies described e.g. by CT-scans, which in turn leads to very large systems of equations.
- phase-field models for fracture result in an unsymmetric coupled problem of at least two fields whose staggered solution typically suffers from slow convergence.

This talk will present a set of recently developed numerical tools to address these challenges. First, a type of local refinement is introduced, which is particularly well suited for transient situations and for which very efficient open-source implementations now exist[1]. This discretization is then combined with the Finite Cell Method, which delivers the possibility to compute phase-field fracture models on complex domains in a straightforward manner. At this point, an extension of the phase-field method for the modelling of rock will be introduced[2].

The computation of problems of physically relevant size requires a distributed, numerical solution on high-performance computers. This necessitates the use of distributed iterative solvers and corresponding preconditioners. Lastly, convergence acceleration techniques for coupled problems are investigated. All methods are evaluated based on a 3-dimensional benchmark problem for brittle fracture[3] before presenting the computation of the introductory example in Figure 1.

Figure 1: Fracture of a core sample of rock.

REFERENCES

[1] P. Kopp, E. Rank, V.M. Calo, S. Kollmannsberger, Efficient multi-level hp-finite elements in arbitrary dimensions, Computer Methods in Applied Mechanics and Engineering. 401 (2022) 115575. https://doi.org/10.1016/j.cma.2022.115575.

[2] L. Hug, M. Potten, G. Stockinger, K. Thuro, S. Kollmannsberger, A three-field phase-field model for mixed-mode fracture in rock based on experimental determination of the mode II fracture toughness, Engineering with Computers. (2022). https://doi.org/10.1007/s00366-022-01684-9.

[3] L. Hug, S. Kollmannsberger, Z. Yosibash, E. Rank, A 3D benchmark problem for crack propagation in brittle fracture, Computer Methods in Applied Mechanics and Engineering. 364 (2020) 112905. https://doi.org/10.1016/j.cma.2020.112905.