11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

PHASE-FIELD MODELING OF HYDRAULIC FRACTURE IN PORO–ELASTIC SOLIDS AT LARGE STRAINS.

S. Mauthe, H. Ulmer and C. Miehe

Institute of Applied Mechanics (CE), University of Stuttgart
Pfaffenwaldring 7, DE-70569 Stuttgart, steffen.mauthe@mechbau.uni-stuttgart.de

Key words: *Coupled Problems, Fracture, Hydraulic Fracturing, Phase Field Modeling.*

Hydraulically driven fracture has gained more and more research activity in the last few years, especially due to the growing interest of the petroleum industry. Hydraulic fracturing, commonly known as fracking, is a technique to increase hydrocarbon production from the subsurface system of reservoirs. Existing models for hydraulic fracturing can be found for example in Boone and Ingraffea [2] or Schrefler et al. [6]. The key challenge for a powerful simulation of this scenario is an effective modeling and numerical implementation of the behavior of the solid skeleton and the fluid phase, the mechanical coupling between the two phases as well as the incorporation of the fracture process.

For this purpose we propose a new compact model structure which is fully variational in nature. To this end we first develop variational potentials for the Biot-type fluid transport in porous media at finite strains, related to the fundamental work Biot [1]. The presented formulation is then coupled to a phase-field approach for fracture which characterizes an intuitive and descriptive regularization of a crack surface that converges for vanishing length-scale parameter to a sharp crack. In contrast to formulations with a sharp-crack discontinuities, the proposed regularized approach has the main advantage of a straightforward modeling of complex crack patterns including branching. For a deeper insight into the phase-field approach to fracture we refer to Miehe et al. [4] for static problems or Hofacker and Miehe [3] for dynamic extension.In this work, we extend these concepts to the coupled problem of fluid transport in porous media at fracture.

Based on the variational potentials we develop a new rate-type mixed variational principle for the evolution problem where the fluid potential plays the role of a mixed variable. For the numerical implementation of the proposed formulation the variational structure is exploited in the numerical scheme by constructing time- and space-discrete incremental potentials for the update problem within a typical time step. The variational structure underlines the inherent symmetry of the coupled problem and advices the use of symmetric solvers for the Newton-type iterative update. This is a strong argument for the proposed variational formulation as it provides a distinctive speedup and reduction of data storage compared with non-symmetric formulations. A similar variational setting for coupled diffusion problems in elastic solids is presented in Miehe et al. [5]. We demonstrate the model capabilities and performance by means of representative numerical examples of complex fracturing scenarios.

References

[1] M.A. Biot. Theory of finite deformations of pourous solids. *Indiana University Mathematics Journal*, 21:597–620, 1972. ISSN 0022-2518.

[2] T. J. Boone and A. R. Ingraffea. A numerical procedure for simulation of hydraulically-driven fracture propagation in poroelastic media. *International Journal for Numerical and Analytical Methods in Geomechanics*, 14:27–47, 1990.

[3] M. Hofacker and C. Miehe. A phase field model of dynamic fracture: Robust field updates for the analysis of complex crack patterns. *International Journal for Numerical Methods in Engineering*, 93:276–301, 2013.

[4] C. Miehe, F. Welschinger, and M. Hofacker. Thermodynamically consistent phase-field models of fracture: Variational principles and multi-field fe implementations. *International Journal for Numerical Methods in Engineering*, 83:1273–1311, 2010.

[5] C. Miehe, S. Mauthe, and H. Ulmer. Formulation and numerical exploitation of mixed variational principles for coupled problems of cahn-hilliard-type and standard diffusion in elastic solids. *submitted to: International Journal for Numerical Methods in Engineering*, 2013.

[6] B.A. Schrefler, S. Secchi, and L. Simoni. On adaptive refinement techniques in multi-field problems including cohesive fracture. *Computer Methods in Applied Mechanics and Engineering*, 195:444 – 461, 2006.