Modeling of fluid-driven fracturing in multiphase porous materials

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ABSTRACT

Fracture of porous materials is a challenging but very important subject in various engineering branches. To mention some, consider in the energy sector the enhanced geothermal systems (EGS) that are applied to generate geothermal electricity. In this, high-pressure water is injected into deep rock layers with low permeability in order to enhance the rock's permeability and, with this, improving the system's efficiency. Additionally, hydraulic fracture is used in petroleum engineering to extract shale gas. In biomechanics, intervertebral disc herniation might occur due to a pressurized nucleus pulposus and can be modeled in the sense of hydraulic fracture.

In this research work, the numerical modeling of fracture in saturated heterogeneous materials is carried out using an extended form of the continuum Theory of Porous Media (TPM), which accounts for the crack nucleation and propagation, deformation of the solid matrix and change in the flow of the interstitial fluids. The extension towards fracture modeling succeeds using the energy-based phase-field modeling (PFM) approach, see e.g. [1].

Starting with the mathematical modeling and material description of fluid-saturated porous materials using the TPM, the proposed treatment assumes steady-state behavior (quasi-static) and neglects all thermal and chemical effects as well as any mass exchange between the constituents. This leads to a strongly coupled system of differential algebraic balance equations (DAE), which demands special numerical schemes for a stable solution. On the other hand, the PFM is a diffusive crack-interface approach that allows simulation of microstructural evolution such as crack propagation on a macroscopic scale. In this, once the critical energy release rate is reached, a crack, associated with local degradation of stiffness, takes place [2].

To reveal the ability of the proposed modeling strategy in capturing the basic features of hydraulic fracture, numerical examples using the finite element method, as in the benchmark two-dimensional problem in Fig. 1, are presented.

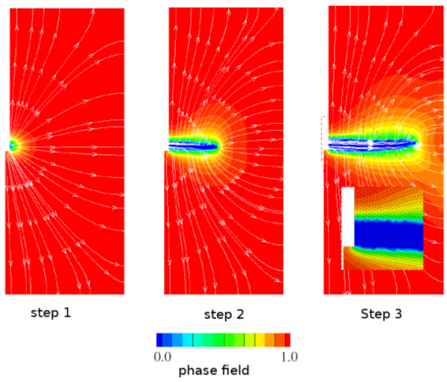

Fig. 1: Hydraulic fracture induced in saturated porous medium [2].

REFERENCES

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[2] Y. Heider and B. Markert, “A phase-field modeling approach of hydraulic fracture in saturated porous media”, Mech. Res. Commun., DOI:10.1016/j.mechrescom.2016.07.002, (2016).