VI International Conference on Computational Methods for Coupled Problems in Science and Engineering – Coupled Problems 2015

Computational simulation of hydraulic fracturing using discrete (GFEM) and continuum (Phase-field) modelling approaches

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ABSTRACT

Hydraulic fracturing is frequently used in geoengineering for the exploitation of deep geothermal reservoirs as well as for shale gas and oil reservoirs [1]. It is characterized by the fluid-induced opening and propagation of fracture zones and constitutes a priori a hydro-mechanically coupled problem. In the presentation, two strategies for the computational modelling of hydraulically induced fracture in water saturated porous materials, both based upon the finite element method, are proposed and compared. One model is based upon the discrete while the other one is using a continuum mechanics approach

One modelling strategy is characterized by a discrete representation of cracks, adopting a hybrid XFEM-Generalized Finite Element Method [2] for the approximation of the displacement and the fluid field in coupled hydro-mechanically finite element analyses. While for the approximation of propagating cracks the XFEM [3], adopting the Heaviside functions in association with crack tip functions, is employed, novel space-time variant enrichment functions for the fluid pressure field in the vicinity of pressurized cracks are constructed from the analytical solution from a related consolidation problem to locally enrich the approximation of the liquid pressure field at discontinuities.

As an alternative model, a continuum mechanics approach [4] - the phase-field model – is used for hydraulic fracture propagation. The crack is represented by a damage field, which is computed as a degree of freedom on the entire domain with the fracture surface energy being considered by the Griffith's criterion and discretized by the phase-field equation [5]. The phase-filed equation is recast in a poromechanics context using the effective stress concept. The solution of the coupled problem is performed using a staggered scheme, in which the equations for porous media and phase-field are solved separately. The permeability in the crack channel is modeled using different assumptions on the fluid transport. One model is based upon continuum micromechanics, which provides up-scaled fluid permeability in the fracture zone depending on the microcrack density, which can be related to the degree of damage [6]. This new model is compared with alternative existing permeability models for joints.

The performance of the proposed GFEM and the phase-field models are investigated by means of numerical analyses of 2D benchmark examples.

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