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

GENERALIZED FINITE ELEMENT METHOD FOR COUPLED HYGRO-MECHANICAL ANALYSIS OF HYDRAULIC FRACTURING PROBLEMS

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Key words: *Generalized Finite Element Method (GFEM), analytical enrichment functions, Extended Finite Element Method (XFEM), poromechanics, multi-phase material, hydraulic fracturing.*

Hydraulic fracturing problems are characterized by a strong interaction between pressurized fluids and cracked porous materials, where the fluid follows a preferential path constituted by the crack and, at the same time, causes further propagation due to the pressure exerted onto the crack faces. Beside cases in which hydraulic fracturing processes may lead to unintended damage of structures or geological formations, intentional hydraulic fracturing of rocks inducing a controlled propagation of fracture zones is applied for the exploitation of deep geothermal reservoirs as well as for shale gas and oil reservoirs. Consideration of interactions between the propagating fracture zone and the fluid flow through the porous material and the crack in numerical analysis requires scale bridging strategies from the spatial scale of the local crack, which usually is much smaller compared to the scale of a typical finite element in poromechanics problems. A recent technique to resolve the small scale of a crack both with respect to the representation of the displacement discontinuities as well as for the fluid flow is to incorporate C^1 discontinuous enrichment functions for the liquid pressure field to represent the jump of the fluid flow orthogonal to the crack in addition to C^0 discontinuous enrichment functions for the displacement field to represent the fracture zone.

In the contribution, a novel Generalized Finite Element Method is proposed for the approximation of the fluid field in coupled hygro-mechanically finite element analyses of hydraulic fracturing problems. While for the approximation of propagating cracks the XFEM [1], adopting the Heaviside functions in association with crack tip functions, is employed, problem specific enrichment functions for the fluid pressure field in the vicinity of pressurized cracks are proposed. Since the liquid pressure within the crack can be viewed as a boundary condition for a consolidation type problem in case of fully saturated porous materials, we suggest to incorporate the analytical solution of a 1D consolidation problem [2] to construct appropriate enrichment functions to locally enrich the approximation of the capillary pressure field at discontinuities. In contrast to classical GFEM schemes, these enrichment functions are now space and time variant functions obtained *a priori* from the exact solutions of the pressure field in space and time according to the analytical solution from a consolidation problem. They are incorporated into the finite element approximation by the *PUM*. The proposed GFEM enrichment of the pore pressure

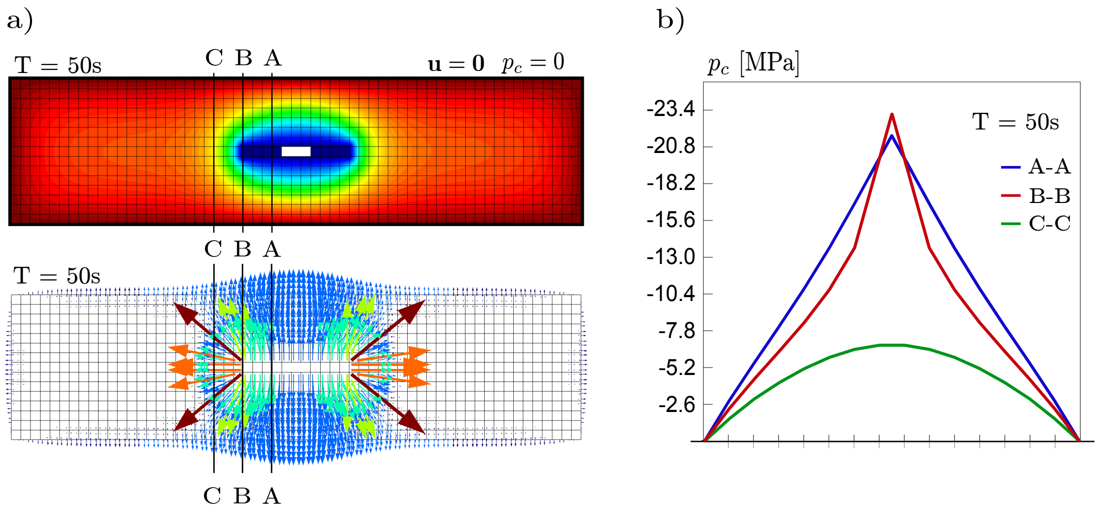

Figure 1: Hydraulic fracturing problem: a) Liquid pressure and fluid flow distribution at time $T = 50s$ b) Pressure distribution at time $T = 50s$ for different sections over the domain

field leads to a significant improvement of the accuracy of the computed solution. As a comparison, also a local enrichment of the pressure field by means of the absolute distance function [3, 4] is considered. In the contribution, in addition to a numerical study of the performance of the proposed GFEM-enrichment method, selected numerical experiments for hydraulic fracturing problems are presented.

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