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X-FEM for Fluid induced Crack Propagation in Partially Saturated Porous Materials using Physically Motivated Enrichment Functions

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ABSTRACT

Hydraulic stimulation of deep petrothermal reservoirs is based upon hydraulic fracturing of the rock i.e. the fluid induced generation and propagation of a system of cracks at a depth of several thousand meters to enable fluid flow through a layer of highly increased temperature used as energy resource at the surface. In a similar form, this technique is also used to exploit deposits of natural oil and shale gas in the underground.

Fluid induced fractures are characterized by a discontinuous displacement and fluid flow across cracks. In the presented paper, a model for hydraulic fracturing processes is proposed within the framework of the theory of poromechanics in conjunction with the Extended Finite Element Method [1]. The discontinuities are modeled by decomposing the corresponding fields, the displacements $\mathbf{u}$ and the capillary pressure p_c additively into a continuous large scale and a discontinuous small scale part. The temperature field is not considered in this model. The additive split of $\mathbf{u}$ and p_c is also applied to the respective test functions involved in the weak formulation of the coupled initial boundary value problem [2,4]. The pressure field p_c is enriched by a nonlinearly decaying function leading to a local increase of the capillary pressure at the discontinuity. This nonlinear function is physically motivated from the 1D analytical solution of the corresponding consolidation problem [3] and is space and time variant. Problems connected with the lack of the partition of unity property in the blending elements adjacent to the crack [5] are eliminated without increasing the degrees of freedom. The proposed approach represents an appropriate extension of the capillary pressure field for the simulation of stimulation processes in geothermal engineering. In the contribution, selected numerical results are presented.

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