A fully coupled HM –XFEM method with cohesive zone model: application to fluid-driven fracture network

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1 Introduction

Predicting occurrence of hydraulically induced damage in geological systems constitutes a major challenge in subsurface engineering. Geo-resource completion (geothermal, oil and gas resources), underground storage management (confinement of hazardous wastes, CO2 storage) or building and maintenance of constructions (tunnels, dams, mines) can be affected by the progressive development of damage due to fluid flow circulation in deformable media. Hydro-mechanical (HM) processes may be due to natural or anthropic forcing that need to be understood and modeled for a variety of problems. There is, therefore, a critical need to build capable numerical models (fully coupled, multi-scale, etc…) to gain better insights into these complex phenomena and thus to improve their predictive capabilities. Historically, classical finite element method (FEM) with joint elements has been widely used in geotechnical engineering but requires computationally expensive remeshing techniques to deal with fracture growth. As an alternative, the extended finite element method (XFEM) [1] consists in using an enriched formulation (additional degrees-of-freedom at the nodes) so that the finite element mesh does not need to conform to the fracture geometry (non-boundary conforming method).

2 Numerical model and results

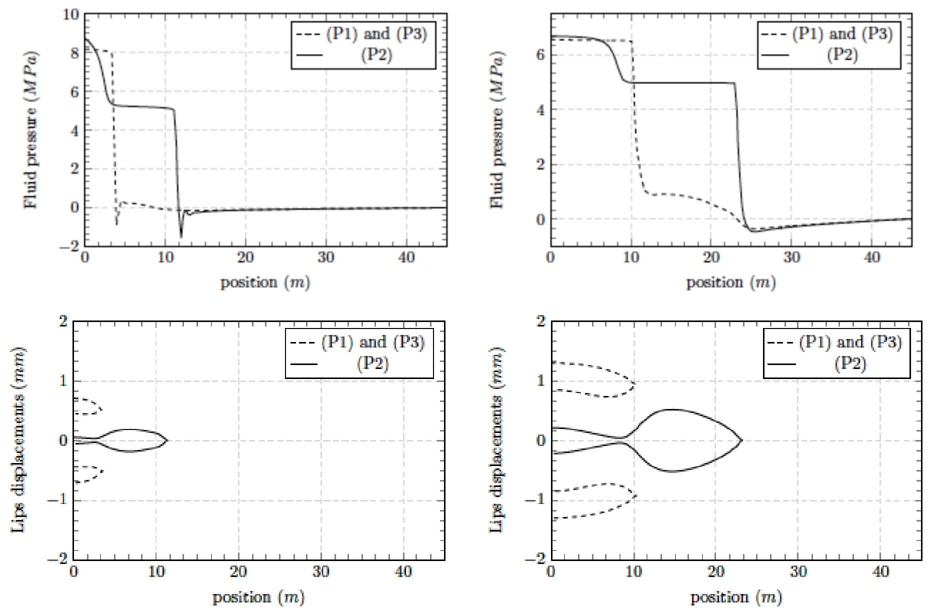

Figure 1: Competition between three hydraulic fractures – fluid pressure along each fracture and lips displacement at short (left) and long times (right).

In the present abstract, we introduce a new numerical model [2] for the fully coupled hydro-mechanical analysis of groundwater flows through poroelastic saturated media. In particular, the presence and eventual propagation of fluid-driven fractures is accounted for within a non-regularized cohesive zone model. The extended finite element method (XFEM) is preferred to a standard finite element spatial discretization in order to easily handle the presence and evolution of discontinuities in the porous medium. We have adapted to HM problems the augmented Lagrangian formulation developed in Lorentz [3] and the classical Talon-Curnier mixed-interface cohesive constitutive law [4]. The fluid pressure inside the fracture is governed by the lubrication equation. The momentum-stress balance equations involving fluid flow and deformation of the solid porous matrix are derived within the framework of the generalized Biot theory. A set of four Lagrange multipliers is introduced to prevent spurious oscillations of the numerical solution at the interface.

Comparisons with numerical results [5] and theoretical solution (KGD model) assess the validity of the model. In addition, the hydro-mechanical interactions between neighboring fractures and the effects of the permeability of the porous medium are investigated. Numerical simulations applied to a non-connected fracture network emphasize the capabilities of the HM-XFEM model to account for the interaction of nearby fractures. In particular, we highlight the competition of both dissipation mechanisms (driven by viscosity or fracture toughness) involved in the propagation of the fracture network.

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