A HYBRID SEQUENTIAL SCHEME FOR BRITTLE HYDRAULIC FRACTURES IN POROELASTIC MEDIA

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We construct a new operator splitting scheme to describe a fluid-driven brittle fracture propagation in a Biot medium based on a time-scale separation assumption. In this context, we propose an alternate hybrid time-stepping scheme, where in the injection step, prior to fracture advance, we explore the framework of the fixed stress split scheme with a hydrodynamic subsystem solved ahead of the geomechanics for a frozen total mean stress. Conversely, after convergence of the fixed stress split iterations, when the pore pressure exceeds a critical value, the coupling between poromechanics and fracture propagation is accomplished by considering a fast time scale, with frozen pore-pressure and Darcy velocity fields. Such a latter step is performed in a separate iteration loop with the elasticity subsystem incorporating the Francfort–Marigo variational model for a thin damage region. In this setting, the evolution of the damaged zone is governed by the sensitivity of the associated shape functional with respect to the nucleation of a small damaged zone, which is computed within the framework of the topological derivative method. The resulting approach is algorithmically described in detail. A numerical assessment of the model is constructed by performing a series of benchmark examples, showing different features of the proposed approach, such as characterization of fracture-activation pressure, crack path forecast, and the ability to capture kinking and bifurcations and quantifying the effects of the in situ stress field on the crack path.

KEY WORDS: *brittle hydraulic fractures, fixed-stress-split, poroelasticity, Francfort–Marigo damage model, topological derivative method*

1. INTRODUCTION

Hydraulic fracturing is a process largely applied by the oil and gas industries. Such a well-stimulating–based technique, also commonly referred to as *fracking*, was first proposed in Clark (1949) and consists in increasing the production area along with enhancing the permeability of the geological formation. The induced fracture network is typically generated by pumping an aqueous phase with controlled composition at high pressure through a pressurized wellbore (Cheng, 2016). Furthermore, in order to extend the size of the propagation region, a substantial pressure increase is required in order to overcome the porous medium resistance along with the *in situ* stress state in the rock layers above the well. The main drawbacks of the technique are related to environmental impacts associated with hydrocarbon leakage to adjacent water resources and possible trigger of induced seismicity. Nevertheless, in spite of the above mentioned issues, from the economical point of view, fracking has been considered one of the most

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