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FRACTURE-BASED ARC-LENGTH CONTROL FOR PHASE FIELD MODELING OF HYDRAULIC FRACTURING

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Hydraulic fracturing plays a crucial role in the extraction of shale gas. There is an urgent requirement for detailed understanding of this process to exploit the immense potential of shale gas in the energy sector and assessing the associated risks in its production. In hydraulic fracturing, crack nucleation, branching, merging and propagation are common phenomena. Complex crack patterns appear as a consequence of the presence of multiple cracks and the anisotropy of the environmental conditions. Over the years hydraulic fracture simulation has primarily been based on discrete fracture models [1, 2]. The inflexibility of this class of fracture models in capturing topologically complex crack patterns has led to the development of phase field models [3, 4]. Since cracks in a phase field description are represented by an order parameter, phase field models have the potential of capturing complex crack patterns.

Since reservoir rock is generally an anisotropic solid containing pores filled with e.g. shale gas, it can be modelled as a poromechanical network. In this contribution we mimic hydraulic fracturing by means of a phase field formulation of fracture in a poromechanical continuum. At this point we restrict our model to the case of a fully saturated isotropic medium with (anisotropic) pre-stresses.

Hydraulic fracturing is a pressure-driven process where crack growth is characterized by stable crack propagation, where inertia effects are typically omitted. We consider the fracture process to be quasi-static, driven by the well pressure. In the case of quasi-static fracture simulations it is common that the parameter by which the loading is governed is not increasing monotonically. The associated phenomena, such as snap back [5], have led to the development of a large variety of arc-length solvers. A path-following constraint based on the dissipation of energy has been observed to yield stable simulations [6, 7]. This robustness is attributed to the fact that energy dissipation is non-decreasing as a consequence of the second law of thermodynamics. In the context of phase field modeling, a direct measure for the dissipation of energy is provided by the implicit representation of the crack surface. In this contribution we use this crack surface functional as a path-following constraint, i.e. we increment the solution by increasing the crack surface area by a prescribed amount.

We study the crack surface path-following constraint using a series of numerical simulations. We start with a benchmark result for crack growth in an isotropic linear elastic continuum. We also present some preliminary results on the simulation of hydraulic fracturing in a two-dimensional setup. When possible, the performance of the path-following constraint is compared to displacement-controlled simulations.

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