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Phase-field modeling of hydraulic fracture with discrete crack topology

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Fluid-driven fracturing plays a vital role in the exploitation of geo-energy sources (geothermal, gas and oil), while also posing challenges for CO2 sequestration and underground energy storage. While the variational phase-field models have shown their power in modeling the involved crack nucleation and propagation coupled with hydro processes, the diffused representation of the cracks impedes the accurate description of the fluid flow in the discrete fracture network and the interplay between the hydraulic and mechanical processes. In this work, we developed a hybrid-dimensional model to realise a staggered description of phase-field fracture in solid media and Reynolds flow in lower-dimensional cracks. This model enables the dynamic reconstruction of 2D or 3D discrete fracture networks (DFNs) based on phase-field point cloud and unconstrained discretisations for solid and fracture domain. To avoid pressure projection when using immerse boundary condition for fluid-solid interaction, a new hydro-mechanical coupling method is proposed and verified with several numerical examples. We demonstrated that this new coupling method is efficient and more favourable when faced with complex DFNs and large-scale parallel computations.

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