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Thermo-hydro-mechanical coupled zero-thickness interface finite elements: benchmarking and application

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Coupled thermo-hydro-mechanical (THM) processes play a key role in subsurface use, e.g. geothermal energy, CO2/H2 storage and geological repository. However, understanding these processes in porous media, in which natural fractures can be present and new fractures can be induced, is non-trivial task. The Cohesive Zone Model (CZM), a numerical technique in the framework of the Finite Element Method (FEM), is one of the possible choices in modelling fracture initiation and propagation due to its simple physical meaning and its mitigation of the need to calculate the stress singularity at the fracture tips that is commonly challenging in methods based on classical linear elastic fracture mechanics. In this work, we developed a THM coupled zero-thickness interface finite element employing CZM. It is developed to allow the simulation of longitudinal and transversal fluid/heat flow inside the fracture. The cubic law is used to simulate the fracture transmissivity as a function of its aperture, while an elasto-damage law is used to characterise the mechanical response of the discontinuity. The method is successfully verified against two analytical solutions: one of the coupled thermo-hydraulic response of a single fracture, and the KGD fracturing model that describes fracture propagation considering hydro-mechanical coupling. An example is then implemented to show how to simulate thermal fracturing without pre-defined fracture direction using the developed interface elements, and sensitivity analysis is performed against the injection rate and fracture energy.

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