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Hydromechanical and Thermomechanical Behaviour of Elastic Fractures during Thermal Stimulation of Naturally Fractured Reservoirs

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During the last two decades, incentives were put in place in order to feed our societies in energy with reduced CO_2 emissions. Various policies have been considered to fulfill this strategy such as replacing coal by natural gas in power plants, producing electricity using CO_2 free resources, and CO_2 sequestration as a remediation for large point-source emitters (e.g. oil sands facilities, coal-fired power plants, and cement kilns). Naturally fractured reservoirs (NFRs) are among those geological structures which play a crucial role in the mentioned energy revolution.

The behavior of fractured reservoirs during production processes is completely different than conventional reservoirs because of the dominant effects of fractures on fluid flux, with attendant issues of fracture fabric complexity and lithological heterogeneity. The level of complexity increases when thermal effects are taking place – as during the thermal stimulation of these stress-sensitive reservoirs in order to enhance the gas production in tight shales and/or increase the local conductivity of the fractures during the development of enhanced geothermal systems – where temperature is introduced as another degree of freedom in addition to pressure and displacement (or effective stress). Study of these stress-pressure-temperature effects requires a thermo-hydro-mechanical (THM) coupling approach, which considers the simultaneous variation of effective stress, pore pressure, and temperature and their interactions.

In this study, thermal, hydraulic and mechanical behavior of partially open and elastic fractures in a homogeneous, isotropic and low permeable porous rock is studied. In order to compare the hydromechanical (HM) and thermomechanical (TM) characteristics of these fractures, three different injection scenarios, i.e. constant isothermal fluid injection rate, constant cooling without any fluid injection and constant cold fluid injection, are considered. Both thermomechanical and hydromechanical behaviors become dominant at different time scales, i.e. HM effects is dominant at early time after injection initiation, whereas the TM effect becomes more dominant at later time as the temperature propagation is slower than pressure propagation in the rock due to different value of hydraulic and thermal diffusivities. Due to the relative similarity of thermoelasticity and poroelasticity on the mechanical behavior of fractures, an analogy between these two mechanisms is introduced which can be used to estimate the effect of one of the mechanisms based on the other one on the mechanical behavior of the considered medium in the cases where only one of the solution exists. There may be merit in developing this work to generate more accurate and higher order functions to represent fractures within a general analogy of THM coupled problems as the computational time of this approach is at least one order less than the conventional THM iterative approaches.