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Modeling thermal stress propagation during hydraulic stimulation of geothermal wells

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A large fraction of the world's water and energy resources are located in naturally fractured reservoirs within the earth's crust. Depending on the lithology and tectonic history of a formation, fracture networks can range from dense and homogeneous highly fractured networks to single large scale fractures dominating the flow behavior. Understanding the dynamics of such reservoirs in terms of flow and transport is crucial to successful application of engineered geothermal systems (also known as enhanced geothermal systems or EGS) for geothermal energy production in the future.

Fractured reservoirs are considered to consist of two distinct separate media, namely the fracture and matrix space respectively. Fractures are generally thin, highly conductive containing only small amounts of fluid, whereas the matrix rock provides high fluid storage but typically has much smaller permeability. Simulation of flow and transport through fractured porous media is challenging due to the high permeability contrast between the fractures and the surrounding rock matrix. However, accurate and efficient simulation of flow through a fracture network is crucial in order to understand, optimize and engineer reservoirs. It has been a research topic for several decades and is still under active research. Accurate fluid flow simulations through field-scale fractured reservoirs are still limited by the power of current computer processing units (CPU).

We present an efficient implementation of the embedded discrete fracture model, which is a promising new technique in modeling the behavior of enhanced geothermal systems. An efficient coupling strategy is determined for numerical performance of the model. We provide new insight into the coupled modeling of fluid flow, heat transport of engineered geothermal reservoirs with focus on the thermal stress changes during the stimulation process. We further investigate the interplay of thermal and poro-elastic stress changes in the reservoir. Combined with a analytical formulation for the injection temperatures in the open hole section of a geothermal well, the stress changes induced during the injection period of reservoir development can be studied.