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A Thermo-Hydro-Mechanical modeling of fracture opening and closing due heat extraction from geothermal reservoir

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Increasing the carbon dioxide concentration in atmosphere become challenging task for the scientific community. To achieve the sustainable growth with minimum pollution in atmosphere requires the development of low carbon technology or switch towards renewable energy. Geothermal energy is one of the promising source of clean energy. Geothermal energy is also considered a sustainable, reliable and least-expensive. This study presents a numerical modeling of subsurface heat extraction from the reservoir. The combine flow, heat transfer and geo-mechanical problem are modeled using FEHM code, which was validated against existing field data, numerical code and commercial software. In FEHM the flow and heat transfer in reservoir are solved by control volume method while for mechanical deformation finite element technique is used. The 3-D computational domain (230m $\times$ 200m $\times$ 1000m) has single horizontal fault/fracture, which is located at 800 m depth from the ground surface. The fracture connects the injection and production wells. The distance between the wells is 100 m. A geothermal gradient 0.08 °C/m is considered. The temperatures at top and bottom boundaries are held fixed as 20 and 100 °C respectively. The zero heat and mass flux boundary conditions are imposed to all vertical side boundaries of the domain. The simulation results for 100 days suggests that the computational domain is sufficiently large as the temperature along the vertical boundaries are not affected by cold-water injection. To model the thermo-poro-elastic deformation, zero all three components of displacement are specified as zero at the bottom. The zero stress condition along all other boundaries allows the boundaries to move freely. The temperature and pressure dependent fluid properties such as density and viscosity with single phase flow in saturated medium is considered. We performed a series of thermo-hydro-mechanical (THM) simulations to show aperture alteration due to cold-water injection. The initial fracture aperture was taken 1mm. The Young's modulus of rock matrix and joint stiffness were taken as 15GPa and 15GPa/m respectively. Our results show that the contraction of rock due to cooling causes the opening of the fracture near injection well. However in some regions where temperature drop is insignificant the compressive stress develops and fracture closes. As the heat extraction continues with time, further contraction of rock causes more aperture growth between the wells. For the above-mentioned computational domain, due to cold-water (20 °C) at mass flow rate 4kg/s, the aperture in the vicinity of the injection well increases by 75%. Our simulation for joint stiffness equal to 50GPa/m, show that the magnitudes of normal tensile and compressive stresses in the fracture/joint are almost same but the aperture alteration is proportionally reduced. Since the joint stiffness is a nonlinear function of opening, it is important to include a suitable nonlinear model for joint opening/closing while simulating the fracture transmissivity alter during heat extraction.