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Heat Extraction at High Flow Rates by Fracture Plugging in Geothermal Reservoirs from Pore to Darcy Scale Considering Local Thermal Non-Equilibrium (LTNE) Conditions

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The existence of fracture network in porous media can have positive or negative effects on matrix-fracture transfer depending on the flow rate. In higher flow rates the efficiency of heat extraction decreases in fractured geothermal reservoirs due to preferential flow through the fractures. The fracture plugging can be considered as a solution to cope with it by diverting flow through porous matrix, resulting in more heat extraction. In present study, the effect of fracture plugging on heat extraction was investigated by cold water injection through the single fractured core plug including an obstacle at different flow rates. Present study indicated that the presence of obstacle in the fracture contributes high heat extraction compared to the absence of it because of fluid penetration into matrix from fracture. The analysis of heat transfer in porous matrix by Local Thermal Equilibrium (LTE) conditions leads to overestimated outlet temperature, thermal analysis with Local Thermal Non-Equilibrium (LTNE) conditions is more accurate, especially, at higher flow rates. In LTE condition both solid and fluid phases are at the same temperature and the average porous media temperature can be scaled with porosity and heat capacities of the fluid and solid phases[1]. In LTNE condition fluid and solid phases have different temperatures. Energy balance equations of the phases are coupled with heat source terms described with interstitial heat transfer coefficient [2]. Numerical studies indicated that in Darcy scale the main controlling parameter is interstitial heat transfer coefficient between solid and fluid phases. Minkowycz et. al [3] investigated the effect of rapid heat source change on NLTE conditions via analytical solutions in Darcy scale. Wang et. al [4] studied NLTE conditions in porous media with trapped fluid - solid matrix system. At LTNE conditions, interstitial heat transfer coefficient of Darcy scale problem can be calculated by averaging heat flows over the solid - fluid interface in pore scale.
In the present study the single fracture-matrix system was selected for cold water injection mimicking geothermal system. Since we are focusing on geothermal energy, there is a flow in our present study, where the Darcy scale parameters are extracted from pore scale model. There is constant injection rate at the inlet and constant pressure at the outlet of the fracture. Other boundaries are no-flow boundaries. Coating the system with epoxy resin allows no flow conditions at the outer surface. Temperature at the outer surface is kept constant.

Fig. 1. Matrix- fracture model domain for thermal transport problem

At the same flow rate temperature of the solid matrix is lower in LTE compared to LTNE condition, which clearly shows an overestimate for heat extraction (Fig. 2). Whereas at the fracture outlet, temperature of LTE is larger, since in LTNE condition there is still a transient heat transfer between the solid and fluid phases. As the flow rate increases, temperature at fracture outlet decreases in both LTE and LTNE conditions (Fig. 3).

Fig. 2. Matrix temperature values for a) LTE and b)LTNE conditions

Fig 3. Fracture temperature output for LTE and LTNE conditions

Participation

In-Person

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