Geomechanical Considerations in Modeling Heat Extraction from Enhanced Geothermal Systems

Esuru R. Okoroafor[a], Adam J. Hawkins[b] and Roland N. Horne[a]

[a]Department of Energy Resources Engineering, Stanford University

[b]Smith School of Chemical and Biomolecular Engineering, Cornell University

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ABSTRACT

In fracture-dominated reservoirs, studies allude to the spatial variation of fracture surfaces across different scales, and have demonstrated that variation in fracture aperture can lead to flow channeling (e.g., Abelin, et al., 1991; Hakami and Larsson, 1996; Tsang and Neretnieks, 1998; Tester, et al., 2006; Watanabe, et al., 2008; Co, et al., 2017; Mattson, et al., 2018). For geothermal energy production, the flow-wetted surface area is of particular interest, because it strongly influences the thermal performance of the reservoir. In an enhanced geothermal type system, cold water is circulated through one or more fractures in a hot rock reservoir and fluid collection at one or more producers returns the heated working fluid to ground surface. Therefore, heat is recovered only across the flow-wetted surface area available between injectors and producers. Under channeled flow conditions, reduced flow-wetted surface area can lead to inadequate heat transfer efficiency (e.g., Neuville, et al., 2010) and, as a consequence, cause premature thermal breakthrough and reduced energy recovery (Co, 2017; Hawkins, et al., 2017, 2018).

In an investigation by Hawkins, et al. (2017), an attempt was made to characterize the spatial distribution of groundwater flow paths and determine the flow-wetted area, the latter then used to predict the thermal performance of the system. Hot water was injected into a cold bedrock 7.6 m below ground surface. A combination of an adsorbing tracer and an inert tracer was used to determine the flow-wetted surface while a thermal-hydraulic model, using the derived flow-wetted area, was employed to predict the system's thermal performance. The experiment lasted for 6 days of continuous fluid circulation. As the experiment progressed in time, the temperatures measured were increasingly greater than the predicted temperatures. According to Hawkins, et al. (2018), possible causes for the deviation include uncertainty in the adsorption reaction parameters; mismatch in the tracer return curves; accuracy of the tracer sampling and analysis instrument; or thermal-mechanical influences which may have caused the flow path to change due to the fracture closing upon heating the reservoir.

This study sought to determine if accounting for thermal-mechanical influences could explain the differences between the measured and predicted temperatures of the experiment. The system was modeled as a coupled thermo-hydro-mechanical system.

The results showed that by using a thermo-hydro-mechanical model, the thermal performance by 6 days (144 hours) was close to the observed data though the profile in the early time was not matched. In addition to the reasons for deviation suggested by Hawkins, et al. (2018), it is possible that there is some degree of uncertainty in the fracture aperture distribution used.

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