Investigating the influence of aperture variability on the fracture surface area in enhanced geothermal reservoirs

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Introduction

To estimate the performance and sustainability of enhanced geothermal systems (EGS), an accurate characterization of the fractures created by hydraulic stimulation is crucial. It is common practice to perform tracer test to obtain relevant reservoir parameters such as reservoir impedance, potential production flow rate as well as fracture surface area [1]. The fracture surface area is one of the most relevant parameters for heat transfer between the rock and the working fluid. However, it is also one of the most uncertain parameters in the characterization of fractured reservoirs.

Generally, fractures of all scales are characterized by two opposite rock surfaces with variable surface roughness. Consequences of varying surface roughness are a heterogeneous local aperture distribution and the formation of channels and barriers within the fracture planes. This significantly affects flow and transport and the resulting fracture surface area. In summary a heterogeneous local aperture distribution is highly relevant for heat extraction.

In a typical rock fracture, the local aperture is statistically represented by a spatially autocorrelated random field, which is characterized by the variogram model and a correlation length [2]. Figure 1 depicts flow and transport channeling in a heterogeneous fracture plane with a normalized correlation length of 0.125.

Approach

In this study, we investigate the influence of correlation length with respect to aperture distribution on fracture surface area and its implication for the results of tracer tests. To this end, numerical simulations of a single circular fracture with a heterogeneous aperture field embedded in a low permeability host rock are performed. The fracture is represented by two-dimensional elements embedded in a three-dimensional model domain. Hence, the heterogeneous aperture field is represented by according parameters. In the fracture plane, flow and tracer transport occurs between an injection and a production well.

The numerically calculated fracture surface area is compared to the results of analytical methods where the fracture surface area is calculated based on the injected and produced tracer rates [1]. Furthermore, our simulations enable the investigation of the influence of different correlation lengths on the results of tracer tests. We show how the aperture variability impacts the results of tracer test and the fractured surface area. Our results contribute to improvement of reservoir characterization and performance assessment of EGS.

Figure 1: Example simulation of solute transport through a fracture plane of unit dimensions with a heterogeneous aperture field and a normalized correlation length of 0.125. Figure (a) shows the normalized aperture field, Figure (b) the normalized velocity, and Figure (c) the mass fraction of the transported solute before breakthrough. We applied a pressure gradient resulting in flow from bottom to top and constant mass fractions of 1 and 0 at the lower and upper boundary, respectively.
References
