An Innovative Computational Approach for Modeling Thermo-hydro Processes within Enhanced Geothermal

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ABSTRACT

An innovative computational approach to capturing the essential aspects of a Enhanced Geothermal System (EGS) is formulated. The modified finite element method is utilized to model transient heat and fluid flow within an EGS reservoir. Three main features are modified to determine their impact on the reservoir: the fracture model, the porous model, and the coupling physical model. For the first feature, the fractures are modeled as a two-dimensional subdomain embedded in a vast three-dimensional rock mass. The fracture model eliminates the need to create slender fractures with a high aspect ratio by allowing reduction of the spatial discretization of the fractures from three- to two-dimensional finite elements. In this model, pseudo three-dimensional equations are adopted to drive the physics of heat and fluid flow in the fractures. In the second feature, a porous subdomain with effective transport properties is modeled to integrate a thermally-shocked region in the reservoir simulation. In the third feature, three-dimensional heat flow in the rock mass is coupled to the two-dimensional heat and fluid flow in the fractures. Numerical examples are computed to illustrate the computational capability of the proposed model to simulate heat and fluid flow in an EGS. Results show that the proposed model is capable of both effectively integrating thermal fractures into reservoir simulation, as well as efficiently tackling the computational burden exerted by high aspect ratio geometries. A parametric analysis is also performed in which the effect of thermal fractures and thermally-shocked region on reservoir performance is evaluated.

SIMULATION RESULTS

The evolution of dimensionless temperature profile of the rock matrix during 30 years of production for (a) CS-A, (b) CS-B, and (c) CS-C cases

- CS-A: Include hydraulic fracture
- CS-B: Include hydraulic fracture + Planar thermal fractures
- CS-C: Include hydraulic fracture + Thermally shocked region + Planar thermal fractures

CONCLUSION

While it is currently assumed that in the presence of a well-connected, large-scale hydraulic fracture, the locally-connected, small-scale thermally-induced fractures do not contribute significantly to the global flow and transport within the EGS reservoir; in this work, we show that thermally-induced fractures can affect the thermal performance of an EGS by providing additional connection area for interflow between the rock matrix and the well-connected, large-scale hydraulic fracture. The results of the numerical example show that integrating thermally-induced fractures into the simulation enhance the thermal performance of the EGS reservoir up to 24% on average over 30 years of production.

The results of the parametric examples show that the penetration length, the aperture, and the permeability of the planar thermal fractures have a negligible effect on the thermal performance of the EGS. Hence, increasing the number of thermal planar fractures from two to six fractures increases the production temperature by 5% on average over the operation time.

The results confirm that adopting the initial concept of the EGS underestimates the performance of EGS technology. Hence, although it is simplified, the proposed hybrid flow model (developed based on a modified conceptual model) evaluates the EGS performance more realistically, which ultimately enhances the overall competitiveness of EGS technology.

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