Using Temperature Signals to Estimate Geometry Parameters in Fractured Geothermal Reservoirs

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Abstract

Geothermal energy is one potential source for energy supply in the currently ongoing turnover. The resource is stored in deep (3 - 5 km) subsurface reservoirs. To estimate the fluid residence-time and therefore efficiency of geothermal power generation knowledge of reservoir characteristics is a prerequisite. Tracer tests are a powerful tool to determine reservoir parameters. Here, tracer is a substance or energy quantity with known physical and chemical behavior, e.g. dyes, heat, radioactive isotopes. Furthermore, state variables such as temperature can be employed for detection. In general the tracer is injected into the reservoir, interacts with the reservoir material and and is finally abstracted again. There are several ways of performing a tracer test. In this study we focus on Single-Well Injection-Withdrawal Experiments (SWIW), also known as Push-Pull Experiments, to determine the reservoir geometry in fractured reservoirs. The experimental design has two phases. Phase one starts with the injection of fluid with a defined temperature. In phase two we immediately abstract the fluid and record the temperature. The analysis aims at the identification of the equivalent fracture width and this information can be obtained just from this temperature signal. For this study we use COMSOL Multiphysics 4.2a and the Subsurface Flow Module. We compare the output of 2D and 3D reservoir models as well as analytical solutions (Kocabas, 2010) of the problem. The model region consists of a rectangle/cuboid with two sub-regions: fracture and bedrock (Figure 1). Additionally the 3D case includes the borehole (Oberdorfer et al., 2011). The temperature signal is evaluated with the heat transfer mode while the coupled flow field is calculated according to Darcy´s law or analytical solutions. The problem is time-dependent so we have to take into account a change in the boundary conditions from a Dirichlet to a Neumann condition. This change is activated at the time of change from the injection to the withdrawal phase (Maier et al., 2011). A numerical problem is encountered at the abrupt temperature change at the thermal front (Figure 2). The resolution in time and space of this step is the numerical "bottleneck" of the problem. Depending on the dimensionless number, describing the mathematical model, we obtain an increasing/decreasing accuracy due to numerical diffusion. In case of high accuracy the three solutions (2D, 3D, analytical) show only negligible deviations. Further efforts were made to stabilize the numerical solution in terms of meshing and time stepping.

Reference

1. Ibrahim Kocabas, “Designing Thermal and Tracer Injection Backflow Tests.” World C.2010 : 25-29(2010).
2. Friedrich Maier et al., Ability of Single-Well Injection-Withdrawal Experiments to Estimate Ground Water Velocity. In: Proceedings of COMSOL Conference 2011 (Stuttgart), CD-ROM-Publication (2011).
3. Philip Oberdorfer et al., Comparison of Borehole Heat Exchangers (BHEs): State of the Art vs. Novel Design Approaches. In: Proceedings of COMSOL Conference 2011 (Stuttgart), CD-ROM-Publication (2011).

Figures used in the abstract

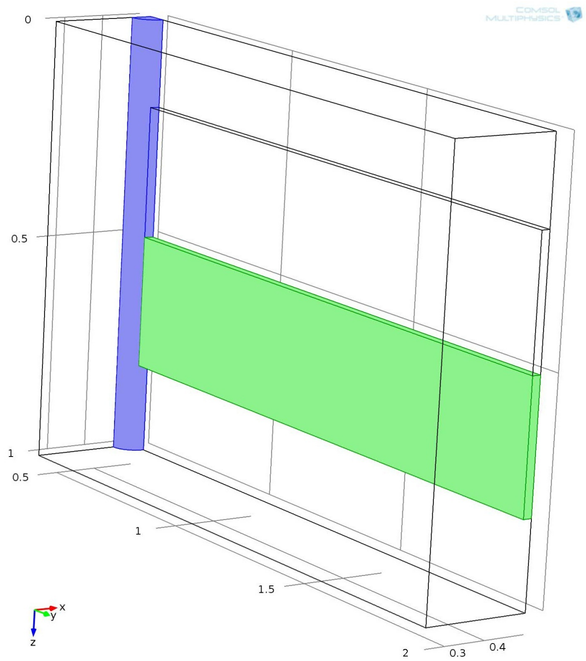

Figure 1: 3D Model area: Blue is the borehole, green the fracture and the outlines indicate the bedrock.

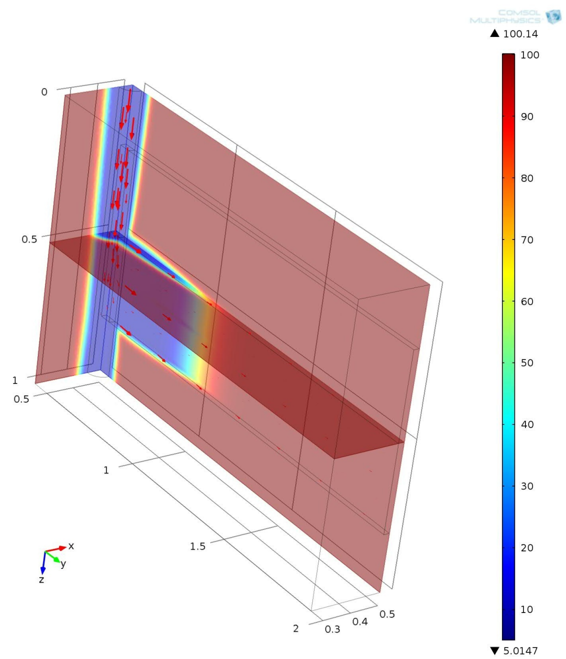

Figure 2: Thermal distribution after 160 s injection time.