Coupling Heat Transfer in Heat Pipe Arrays with Subsurface Porous Media Flow for Long Time Predictions of Solar Rechargeable Geothermal Systems

Phillip Oberdorfer[1], Rui Hu[1], Mohammad Azizur Rahman[1], Ekkehard Holzbecher[1], Martin sauter[1], Peter Pärisch[2]

[1]Applied Geology, Geoscience Centre, University of Göttingen, Göttingen, Germany
[2]Institute for Solar Energy Research Hameln/Emmerthal (ISFH), Emmerthal, Germany

Abstract

An increased share of renewable energies is regarded as an integral part of a strategy towards a sustainable future. With regard to the heat supply sector this may be achieved using solar thermal collectors or heat pump systems with borehole heat exchangers. During the last years solar thermal and geothermal systems have generally been installed separately. Now, several proposals are discussed in which the two technologies are combined as both can benefit from each other. The EFRE project Geo-Solar-WP (high-efficient heat pump systems with geothermal and solar thermal energy sources) handles the different aspects of coupled thermal systems. Our part of the work is focused mainly on transport processes of heat and groundwater in the subsurface. Here we intend to present our modelling work using COMSOL Multiphysics 4.2 and 4.3. For accurate long-time predictions of thermal rechargeable subsurface heat pipes, a numerical model must consider different physical aspects, constraints and processes. The heat transport inside the pipes, as well as the heat exchange between the pipes and the subsurface are calculated using heat transfer in solids, in fluids and in porous media. The latter can be strongly influenced by subsurface flow fields. In this study, this phenomenon was considered by coupling the heat transport with Darcy's Law and considering the subsurface parameters. The heterogeneous distribution of these parameters is introduced using results of experimental data of a novel hydraulic tomography technique [1]. The already obtained results promise a good performance in further simulations. We conducted runs of a single heat pipe at our field test site and compared the experimental data of the thermal regime (Pärisch et al., 2011) with numerical output from the COMSOL model [2]. Figure 1 shows the experimentally and numerically obtained pipe outflow temperatures. Apart from the early times, which are strongly influenced of the insufficiently known initial conditions, the model shows a behavior comparable to the real situation.
We will present model results and experimental data for extended filed test constellations of the field test site. Three pipes are currently examined in an array of experimental test runs in order to get an improved understanding of the well interdependence and the influence of subsurface flow. Figure 2 shows a simulation result of the system on the assumption of a mean ambient groundwater velocity of 1 m/d. Furthermore, we intend to utilize the new Pipe Flow Module from COMSOL

Multiphysics version 4.3 and compare the results with other pipe model approaches.

Reference

1. Hu, R. et al. (2011): Hydraulic tomography analog outcrop study: Combining travel time and steady shape inversion. Journal of Hydrology, Volume 409, Issues 1-2, 28 October 2011, Pages 350-362. doi:10.1016/j.jhydrol.2011.08.031.

2. Oberdorfer P., Maier F., and Holzbecher E. (2011): Comparison of Borehole Heat Exchangers (BHEs): State of the Art vs. Novel Design Approaches. In: Proceedings of COMSOL Conference 2011 (Stuttgart), CD-ROM-Publication.

Figures used in the abstract

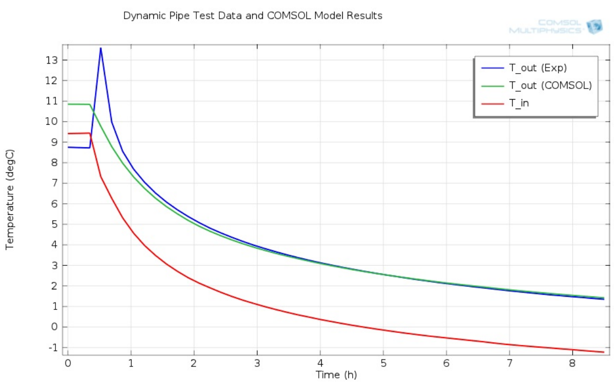

Figure 1: Dynamic pipe test data and COMSOL model results.

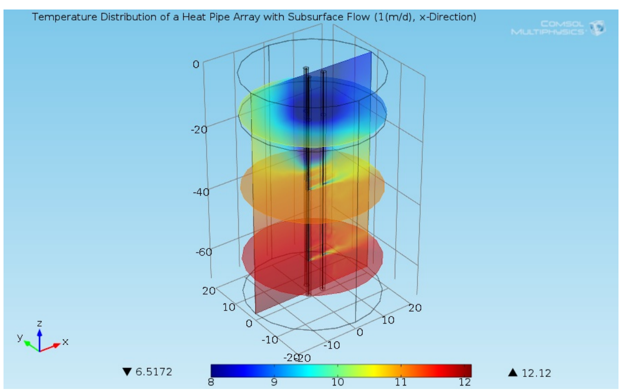

Figure 2: Temperature distribution of a heat pipe array with subsurface flow.