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Analysis of thermal response tests (TRT) using high resolution numerical simulations

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Thermal conductivity and borehole resistance are the most relevant parameters for the site-specific planning and design of borehole heat exchangers (BHE). Both are commonly determined using thermal response tests (TRT). The latter evaluates the temporal development of the mean fluid temperature within an installed BHE, which is generated by a controlled heat injection or extraction. The TRT standard interpretation is based on the Kelvin line source equation, which is an analytical approach and thus cannot consider all details of a BHE. To investigate the role of these limitations on TRT interpretation, a systematic TRT-analysis with a detailed numerical model is performed. Synthetic real-case oriented test cases are generated with a high resolution finite-element-model of double-U tubes in FEFLOW. The effects of the ambient geothermal gradient and of the detailed geometry of the BHE are analyzed, aspects that are usually not considered in the analytical approach. The simulations show remarkable variability of the mean fluid temperature in the BHE. Using a vertical geothermal heat flux of 0.07 W/m^2, the computed effective thermal conductivity decreases by 0.14 W/(mK) meaning a decline by 6.4%. At the same time the calculated borehole resistance increases from 0.086 to 0.101 (mK)/W, i.e. it rises by 17.4%. The effect of the geometry is examined by varying the distance between the tubes in the BHE. This leads to no significant change of the calculated thermal conductivity. However, the computed thermal borehole resistance is highly sensitive. The values shift from 0.06 (mK)/W (for the closest arrangement of the tubes) to 0.17 (mK)/W (for the greatest possible distance between the tubes). The presented relationships clearly show the uncertainties in standard TRT interpretation and demonstrate that in many situations a more detailed evaluation concept is needed.