Extraction of Thermal Characteristics of Surrounding Geological Layers of a Geothermal Heat Exchanger By COMSOL Multiphysics® Simulations

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Abstract

Introduction:
A Geothermal Heat Exchanger (BHE) is an efficient heat source or sink for Heating, Ventilation, and Air Conditioning (HVAC) with the drawback that its drilling costs penalize the dissemination of this technology. In the optimum design of a BHE, it is very important to know the thermal behavior of geological layers crossed by perforation, in order to maximize the average power transferred per meter drilled. Commonly, with a Thermal Response Test (TRT), two basics parameters are obtained, borehole resistance and thermal conductivity of subsurface surrounding, being this last based on the Infinite Line Source (ILS) model developed by Kelvin. When used as a mean to dimension a BHE field for a HVAC system, these two mentioned parameters allow us to obtain the total length of pipes that the buried exchanger is made of, but they do not permit us evaluating the optimal structure of the BHE field (number of boreholes vs drilling depth) that maximizes the relationship between heat transfer and length of pipes.
In this abstract contribution we introduce a study about an experimental BHE, on which we want to know the thermal features of the surrounding ground. While drilling, the geologic profile was obtained, as the diagram of figure 1 shows. During the performance of a heat injection TRT of 1 kW, the temperature profile was measured in an auxiliary pipe inserted into the bore. The auxiliary tube is one of the two U-pipes that comprise the borehole. Figure 2 shows a cross sectional of pipe into borehole. Finally, figure 3 shows the profiles along the auxiliary pipe collected in different times during the TRT.
Use of COMSOL Multiphysics® software:
From an experimental BHE of 30 meters deep and 5 geological layers, it has been developed a 3D model in COMSOL Multiphysics®. In simulations, the physics nodes used have been: flow in pipes and heat transfer in solids; configuring the study in time dependent with a step of 600 seconds to complete a simulation of 7 days.
Some simulations have been conducted in order to fit the temperature profile into the auxiliary pipe of the model with data measured during a TRT in the experimental BHE.

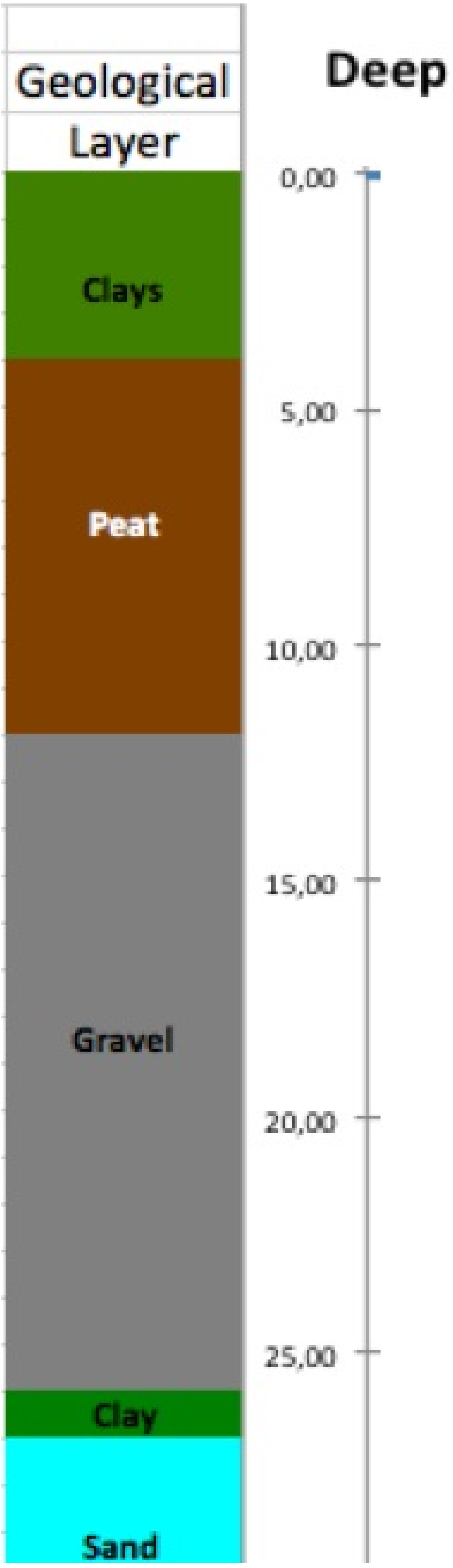
Results:
By means of adjusting the thermal characteristics of the surrounding layers a good agreement has been reached. Figure 4 shows a superposition of temperature measurements during TRT and

temperatures obtained in simulation. The thermal conductivity of geological layers in this fit varies from 2.2 to 6 W/mK. The more conductive layer is located from 24 to 26 meters depth. The average thermal conductivity obtained from the TRT is 2.66 W/mK.

Conclusion:

Considering simulations and several measured temperature data during a TRT, it is possible to obtain a model in COMSOL Multiphysics® to estimate the thermal parameters of the geological layers which surround a BHE. Thanks to this method is possible to identify the more conductive layer and take advantage of such a technique in order to minimize the drilling length.

Figures used in the abstract



Geological Layer
Deep
0,00
5,00
10,00
15,00
20,00
25,00
Clays
Peat
Gravel
Clay
Sand

Figure 1: Profiles of geological layers.

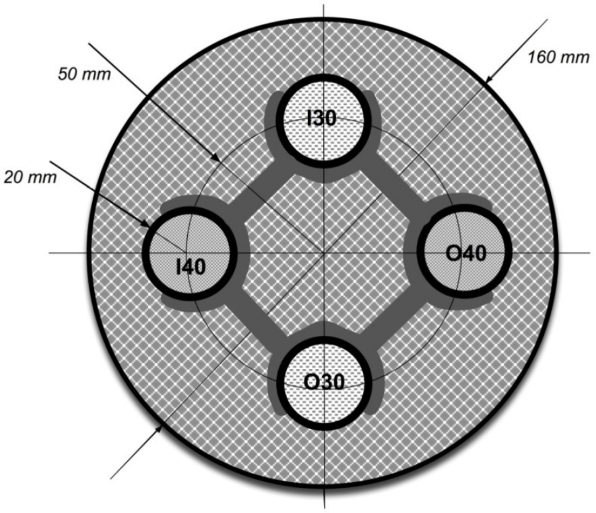


Figure 2: Double U-pipe into borehole.

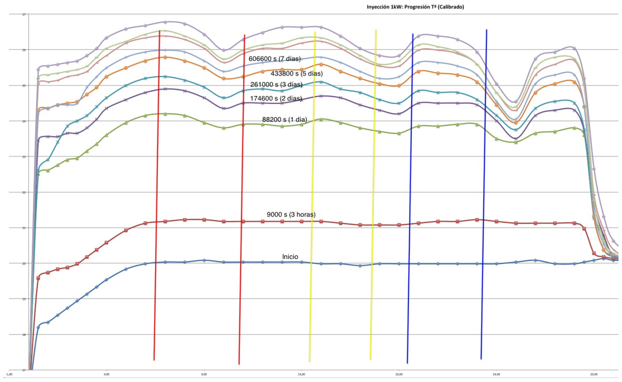


Figure 3: Temperature profiles into auxiliary pipe.

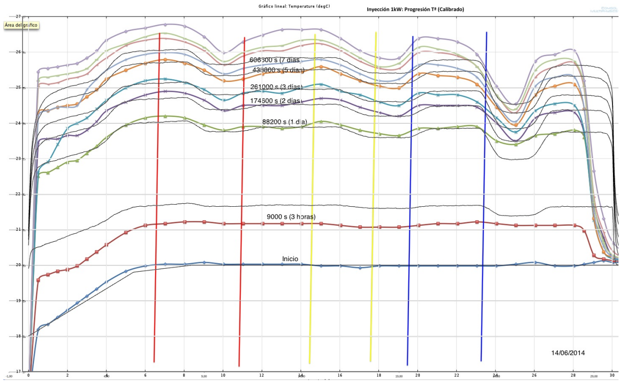


Figure 4: Fit of temperature profiles.