IV[th] International Symposium on Innovative Materials for Processes in Energy Systems 2016

Numerical estimation of the temperature field around the borehole thermal energy storage using buried temperature sensors

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Abstract

One of the thermal energy storage systems is borehole thermal energy storage (BTES). Such technology gives opportunity to store heat/cold in large scale into the ground and groundwater in the summer/winter, and extract it during winter/summer. In order to develop such system, performance of borehole heat exchanger must be evaluated. Thus, the main objective of the current study was to obtain deeper insight into temperature field around borehole heat exchanger during thermal response test using buried Pt100 temperature sensors installed along at an every 10 meter depth along 50 meter single U-type borehole heat exchanger which was developed at Al-Farabi Kazakh National University.

1. Introduction

Thermal energy storage system often plays important role in cooling and heating applications. Once thermal energy is harvested from renewable energy sources, it can be used for necessary purposes and excess energy might be stored to TES system with the purpose of leveling out differences between demand and supply during off-pick times. One of the technologies which allows storing thermal energy in a large-scale, is Underground Thermal Energy Storage (UTES). Such technology gives opportunity to store heat into the ground and/or groundwater in the summer, and extract it during winter. In a similar way, cold can be stored during winter and extracted in the summer for cooling purposes. Several types of large-scale or seasonal thermal energy storages are well established worldwide. One of the most common systems is borehole thermal energy storage (BTES). BTES is attractive since: (i) construction costs are less compared to other UTES systems, can be installed almost everywhere except in locations where in the underground there are emptied caverns or high pressure geysers; and it is long-term system if borehole heat exchanger is installed by carefully following the installation rules [1, 2]. With the purpose of studying BTES system, at Al-Farabi Kazakh National University there was 50 meter single U-type borehole thermal energy storage developed. In this work, we present results of the study dedicated to the performance of this BTES.

2. Experimental installation and results

One of the methods to evaluate the performance of BTES is to carry out in situ thermal response test (TRT). TRT is carried out by means of spacially developed installation. Such installation was also developed at Al-Farabi Kazakh National University in 2015. TRT installation consists of the parts such as 3 kW heater, a pump with flow rate of 80 L/min, 8-liter expansion tank, water filter, monometer, air remover and connecting pipes wrapped with insulation materials. Connecting pipes of the test installation is attached to the borehole heat exchanger when thermal properties of the ground need to be evaluated. Also, temperature sensors Pt100 were installed along borehole heat exchanger at every 10 meters to record the temperature history during the thermal response test (Fig.1, a).

The results of the BTES performance evaluation based on the thermal response test and buried temperature sensors were illustrated in Fig. 1 b) and Fig. 2. It can be noticed from the results in Fig. 1, b) that at 10 meter depth the thermal energy was dissipated faster than others since there were aquifer at that depth. The thermal history along the borehole illustrated in Fig. 1, b) is for 24 hours. The temperature measurements with buried temperature sensors along the borehole during the overall test duration (which is 7 days) were shown in Fig. 2, a).

a) b)

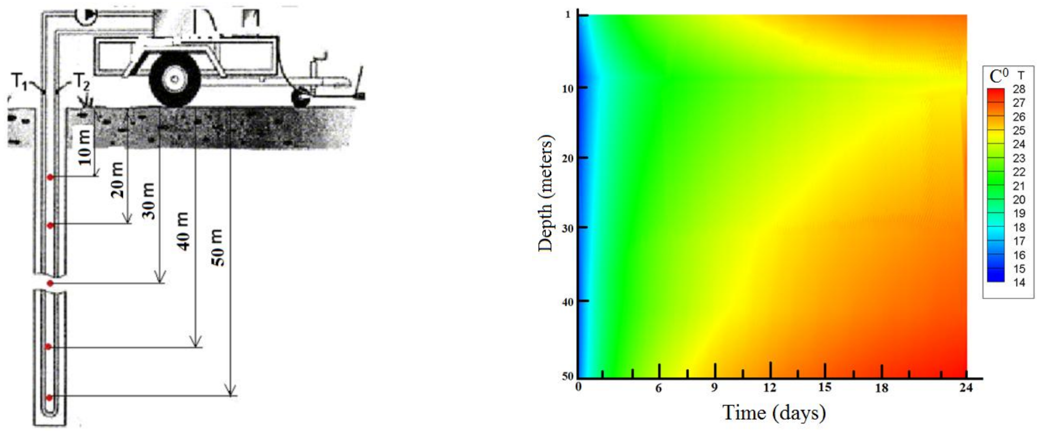

Fig. 2: a) Schematic diagram of the TRT installation and depths of the buried temperature sensors; and b) Temperature change along the borehole over time measured form buried Pt100 sensors along BTES.

Using the experimental data, numerical analysis was carried out to estimate the temperature field around the borehole heat exchanger. In the numerical analysis, surrounding soil was considered as a porous media with the presence of the groundwater flow at 10 meters (identified during the drilling process). Convective heat transfer process in the heat exchanger was modeled using energy balance between inlet and outlet pipes, and the grouting material [3, 4]. The results of the three dimensional modeling of the thermal response test was provided in Fig. 2, b). It can be seen from the modeling result, the fluid flow in the porous aquifer takes out some thermal energy from the circulating working fluid. Indeed, the modeling results were agreed with the experimental data which was important in finding out the correctness of the modeling results.

a) b)

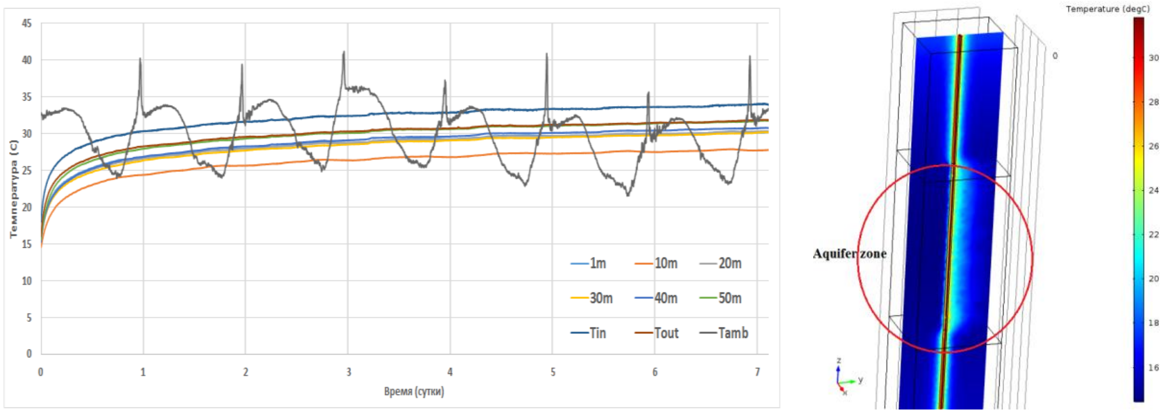

Fig.1. a) Temperature measurement results along BTES and the ambient temperature variation during the test; b) modeling of TRT process and temperature change around the borehole heat exchanger.

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