BHE Field Design By Superposition of Effects in Space and Time

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Abstract

When designing a Borehole Heat Exchanger (BHE) field special attention should be devoted to grant its long-term sustainability, especially in the case of unbalanced seasonal loads and negligible groundwater movement. Usually, the method developed by Kavanaugh and Rafferty [1] and recommended by ASHRAE [2] is adopted to design BHE fields. While for a single BHE with unbalanced seasonal loads the long-term sustainability has been verified both experimentally and theoretically [3, 4], medium or large BHE fields with unbalanced seasonal loads, in the absence of groundwater movement, can reach a critical condition in a few decades [5, 6]. On the other hand, the groundwater flow has an important effect on the long-term sustainability [7, 8]. The results of the researches cited above show that the ASHRAE method cannot be considered as satisfactory in the case of medium or large BHE fields with unbalanced seasonal loads. In fact, it does not ensure the long-term sustainability in the absence of groundwater flow, and does not take into account the effects of the groundwater flow. In the present paper, a new design method for BHE fields in the absence of groundwater flow is presented, based on the superposition of effects. A unit step heat load, with duration of one month, is considered, and its effects are evaluated (Figure 1). Then, the effects of any periodic heat load with a period of one year can be obtained by a weighted sum of the effects of the unit step heat load, properly displaced in time. Each BHE in the field is modeled as a cylindrical heat source in an infinite solid (Figure 2). The interference between BHEs is evaluated by the superposition of effects in space. The result of the computations is a set of dimensionless equations that, properly superimposed, yield the time evolution of the dimensionless temperature at the interface between fluid and tubes for the most critical BHE, for a period of 50 years, for several typical configurations of BHE fields. The effects of the hourly peak loads can then be added by employing the results obtained in [8], which are independent of the groundwater velocity and the BHE field geometry.

Reference

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[8] E. Zanchini, S. Lazzari, A. Priarone, Long-term performance of large borehole heat exchanger fields with unbalanced seasonal loads and groundwater flow, Energy 38 (2012) 66-77.

Figures used in the abstract

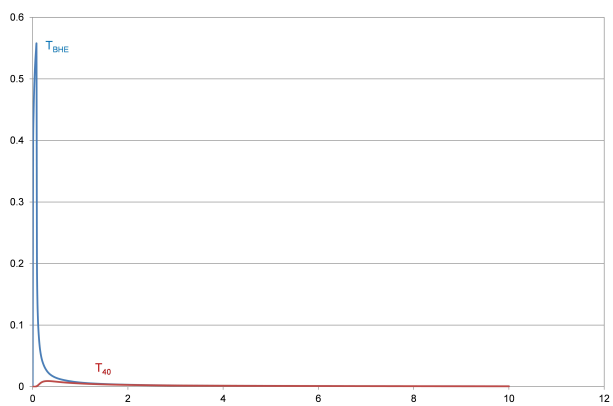

Figure 1: Time evolution of the dimensionless temperature at the BHE surface and at a distance of 40 diameters from the BHE axis, produced by the one-month unit step heat load imposed on the BHE.

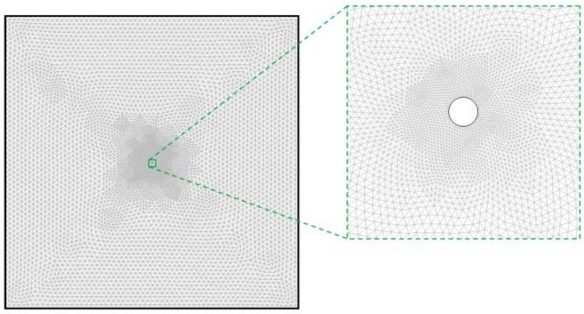

Figure 2: Unstructured triangular mesh around the BHE.