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# A review on heat transfer enhancement of borehole heat exchanger

Jun Zhao[a,*], Yang Li[a], Junyao Wang[a]

[a]*Key Laboratory of Efficient Utilization of Low and Medium Grade Energy (Tianjin University), Ministry of Education of China, Tianjin 300072, China*

**Abstract**

The heat transfer enhancements of borehole heat exchanger (BHE) have been intensively studied which strongly influences the performance of ground-coupled heat pump (GCHP) systems. In this paper, some typical heat transfer enhancement methods of BHE are reviewed based on BHE designs, grout materials and the influence of artificial groundwater flow. Features and feasibility of different methods have been discussed for the different applications.


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*Keywords:* Borehole heat exchanger; Ground coupled heat pump; Heat transfer enhancement

## 1. Introduction

Ground source heat pump (GSHP) systems have been globally applied in various buildings as heating and cooling could be supplied efficiently with low carbon emissions. Taking China as an example, from 2010 to 2014 the annual average growth rate of geothermal utilization was up to 18.7%.The ground-coupled heat pump (GCHP) system is one of a typical GSHP technologies, which mainly uses borehole heat exchanger (BHE) for heat transfer process. As the efficiency of the whole GCHP system is strongly influenced by the performance of BHE, large numbers of researches have been carried out in every aspect for BHE technologies.

Basically, there are mainly four factors affecting the heat transfer performance of the BHE: the BHE heat transfer efficiency, the grout material heat transfer coefficient, the underground soil heat transfer efficiency and the groundwater flow influence effect. Therefore, lots of thermal transfer enhancement

* Corresponding author. Tel.: +86-22-27407320; fax: +86-22-27407320.
*E-mail address:* zhaojun@tju.edu.cn.


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approaches have been proposed and studied as well as already been applied in practical projects. However, the feasibility and compatibility of different enhancement methods under varying application conditions are still remained to be further demonstrated, thus a comprehensive review and comparison is necessary.

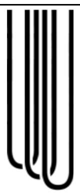
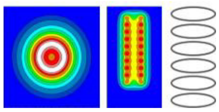
This paper is aim to review the existing heat transfer enhancement methods of BHE, along with their experiment or simulation results. Different categories of enhancement technologies are reviewed with a comparison and summarize of their technical feasibility, economical efficiency and other features. The suitable method for different application scenario is discussed.

## 2. Advanced design of BHE

### *2.1. Advanced design with larger heat transfer area*

Obviously, BHE with larger heat transfer area can achieve better heat transfer effect. Thus, three types of advanced BHE have been studied: the multi-tube BHE, the helical BHE and the coaxial BHE. The sketches and some typical research results are summarized in Table 1.

Table 1. Advanced design of the BHE with larger heat transfer area

| Type | Sketch | Source | Figures | Key findings |
|---|---|---|---|---|
| Multi-tube BHE |  | Aydın et al. [1] |  | The heat transfer rate of the 3U-tubes BHE increased by 25% than the single U-tube BHE under the designed experimental condition. However the performance improvements of the 4U and 5U-tubes BHE are insignificant indicated by the simulation results. |
| | | Park et al. [2] |  | The thermal resistance of the 3U-tubes BHE decreased by 24.8% than the W-shaped BHE based on a TRT test. However, the superior performance could be achieved only for an intermediate operation period rather than a continuous operation time according to a long term simulation. |
| Helical BHE |  | Zarrella et al. [3] |  | The growth of the heat transfer rate of the helical BHE was up to 40% compared with the double U-tube BHE at peak load. Furthermore, a simulation result shows that when the pitch of the helical decreased by 50%, the peak load could reach an increase by about 14%. |
| | | Zhang et al. [4] |  | The ring-coil model can reflect the real physical configuration of the helical BHE in a more approximation method. It is indicated that the beneficial effect of the groundwater flow became more obviously with the passage of time as well as the increase of the seepage velocity. |
| Coaxial BHE |  | Zhao et al. [5] |  | Due to the effect of natural convection, the heat transfer rate of the coaxial BHE inclines to stabilization at the far-field. The dimensionless temperature gradient along with the outer wall of the BHE has a linear relationship with the non-dimensional height. |
| | | Acuña [6] |  | The theoretical conductive thermal resistance of the HDPE coaxial BHE is about 30.4% lower than that of the single U-tube BHE with the same configuration. Besides, the pressure drop of this coaxial BHE is significantly lower than that of the U-tube BHE. |