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# Modelling of a horizontal geo heat exchanger with an internal source term approach

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**Abstract**

This paper presents a new approach to considering the effect of seasonal changes in soil temperature on the performance of a horizontal geo heat exchanger. It is different from the existing models which consider seasonal changes in soil temperature by applying a real energy balance on the ground surface. In the new model, the seasonal changes in soil temperature, which are affected by the thermal interaction between the ground and the atmosphere, are expressed as an internal source term. The value of the internal source term depends on the soil density, soil specific heat, soil temperature difference during summer and winter, and time period. The simulation results show that the new approach, which takes into account the effect of periodic soil temperature fluctuations on the performance of the horizontal geo heat exchanger, is valid.


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*Keywords:* Geo-heat exchanger; thermal modelling; internal source term

## 1. Introduction

In recent years, geo heat exchangers (GHEs) have become more attractive and widely used for heating and cooling applications. GHEs are used to harvest shallow geothermal resources, in which compared to the air temperature, the ground temperature is warmer in winter and cooler in summer [1]. Therefore, GHEs can be used to harness the relatively stable temperature of the ground to increase the efficiency of conventional heat pumps in the winter and air conditioning systems in the summer.

There have been many studies on the modelling of horizontal GHEs. One of challenges involved in the modelling of the horizontal GHEs is considering periodic soil temperature fluctuations. A comprehensive model of a horizontal GHE has been presented by Demir et al [2]. They consider the periodic soil temperature fluctuations by applying the real energy balance on the ground surface. However, their model is complex.

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Nomenclature

| | | | |
|---|---|---|---|
| $A$ | area ($m^2$) | $T$ | Temperature (K) |
| $c$ | specific heat (J/kg K) | $t$ | time (s) |
| $d_{in}$ | inner pipe diameter (m) | $V$ | volume ($m^3$) |
| $H$ | internal source term ($W/m^3$) | $\rho$ | density ($kg/m^3$) |
| $k$ | soil conductivity (W/m.K) | $\alpha$ | thermal diffusivity ($m^2/s$) |
| $m$ | mass flow rate (kg/s) | $h$ | convection coefficient ($W/m^2.K$) |

This paper presents a novel three dimensional unsteady heat transfer model for a horizontal GHE. In the model, seasonal changes in soil temperature, caused by external factors such as: solar radiation, evaporation, wind gust, ambient temperature and vegetation cover, are presented as an internal source term for the first time. This approach, in which the value of internal source term depends on soil density, soil specific heat, soil temperature difference during summer and winter, and time period, is more practical to use.

## 2. Heat transfer model of the horizontal GHE

Heat transfer analysis on the horizontal GHE is performed by applying an energy conservation principle. The three dimensional profile of soil temperature is modelled by dividing the soil and pipe into small segments and solving the two dimensional unsteady heat conduction equation for each of those individual segments. The equation is given as

$$\frac{1}{\alpha_s}\frac{\partial T_s}{\partial t} = \frac{\partial^2 T_s}{\partial x^2} + \frac{\partial^2 T_s}{\partial y^2} + \frac{H_s}{k_s} \tag{1}$$

The fluid temperature is calculated using relations derived from the equation of energy balance. The change of total energy of fluid in control volume is equal to the flux of energy entering and leaving the control volume and the heat flux transferred through the pipe surface.

$$c_f \rho_f A \frac{\partial T_f}{\partial t} = \pi d_{in} h_f (T_p - T_f) - \dot{m}_f c_f \frac{\partial T_f}{\partial z} \tag{2}$$

The pipe temperature is also calculated based on transient analysis, in which the pipe exchanges heat with working fluid as convection and then is transferred to the soil domain as conduction. The governing equation for the pipe is given as

$$c_p \rho_p V_p \frac{\partial T_p}{\partial t} = A h_f (T_f - T_p) + \frac{k_s A}{0.5\Delta x}(T_s - T_p) \tag{3}$$

The above differential equations are solved by using an explicit finite different method. Fig. 1 shows the computational domain of the horizontal GHE. It is considered to be from the centre line of the pipe to the mid-span of the distance between the pipes. In this model, a new approach to consider the seasonal changes in soil temperature is proposed. It is different from the existing model which considers seasonal changes in soil temperature by applying a real energy balance on the ground surface. In this model, the soil temperature's seasonal change is calculated by using an internal source term. This approach is more practical to use, as the internal source term is calculated based on the differences in soil temperature during summer and winter. The values of the soil temperature changes during summer and winter can be obtained from the measurement results. Since the subsurface temperature varies over the depth of the soil, different depths of the ground would have different source term values. The internal heat source could be calculated as

$$H = \rho_s c_s \frac{\Delta T_s}{\Delta t} \tag{4}$$