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Using Geothermal Energy for cooling - Parametric study

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Abstract

Geothermal heat pump is an efficient application derived from geothermal energy. It exploits earth as a heat provenance to extract heat from it and heat space in winter, or it uses earth as heat sink to transform heat to it and cool the space during summer. This paper presents a parametric study to investigate the effects of inlet and outlet water temperatures and ground temperature on the length of the pipe of a horizontal geothermal heat pump system during cooling process. The type of the considered pipe is Poliplex - PE100 Series 1 – polyethylene of 16 mm inner diameter and 20 mm outer diameter. The obtained results revealed that at 30 °C water inlet temperature, 27 °C water outlet temperature and 21 °C ground temperature the length of pipe needed is 716 m. Also, the results showed that higher water inlet temperature and ground temperature increases the required pipe length; however, higher water outlet temperature decreases the needed length of the pipe.

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Keywords: geothermal energy, horizontal geothermal heat pump, length of the pipe, water inlet temperature, water outlet temperature, ground temperature.

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1. Introduction

The permanent aggravation of greenhouse effect and the rise in the price of conventional sources of energy promoted scientists to search for solutions such as heat recovery [1-7] and renewable energy sources [8-13]. Geothermal energy is distinguished as a clean, free and environmentally friendly renewable energy. Geothermal

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energy [14-18] is a ground energy source generated from the difference in temperature gradient between ambient and ground temperatures. Geothermal heat pump system utilizes heat working fluid to circulate in a closed loop, where it exploits soil as thermal source or sink for space heating or cooling. Heat pump, heat exchanger and distribution system are the main components of geothermal heat pump system.

Horizontal geothermal heat pump [19-22] is one of the most important types of geothermal heat pump. It is mostly efficient for residential installations due to its cost. Besides, it is commonly used when sufficient area is available. Such system requires trenches to be dug where up to six pipes are buried horizontally in each trench. Each trench is far ten to fifteen feet from the other trench. The pipes are connected in parallel and separated by minimum distance equal to one foot.

In designing a horizontal geothermal heat pump it is important to estimate the required length of the pipes which is affected by several parameters. From this point, the present work deal with a parametric study which discusses the influence of hot water inlet temperature, ground temperature and water outlet temperature (leaving the ground), in the cooling mode.

Nomenclature

A	cross section area of the pipe (m^2)
C_p	specific heat of water (Kg/s)
D	inner diameter of the pipe (m)
h	convective heat transfer coefficient ($w/m^2.K$)
K	thermal conductivity of polyethylene (0.5 w/m.K)
L	length of the pipe (m)
$\dot{m}$	mass flow rate of water (Kg/s)
Nu	Nusselt number
Pr	Prandtl number (5.43 at temperature 30°C)
r	radius (m)
R	resistance (K/w)
Re	Reynolds number
S	conduction shape factor
Z	depth of the pipe underground (m)
ΔT	temperature difference (°C)
ΔT_{log}	logarithmic mean temperature difference
μ	dynamic viscosity of water (0.76×10^{-3} Kg/m.s)
$\tilde{V}$	volumetric flow rate of water (m^3/s)
ρ	density of water (995.7 Kg/m^3)

Subscripts

cond,p	conduction in the pipe
cond,s	conduction in the soil
conv,w	convection of water
i	inner
o	outer
t	total

2. Thermal modeling

The thermal model of the pipes in geothermal heat pump is based on calculation of the rate of heat exchange which is obtained from the formula of equation (1).