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Experimental investigation of the cooling performance of a ground source heat pump system in Denizli, Turkey

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ABSTRACT

The ground source heat pump system (GSHP) is installed at PamukkaleUniversity in Denizli, Turkey. The U-bend ground heat exchanger pipe length of 225 m was buried in soil at 110 m depth. In the 2008 cooling season, performance coefficients of the heat pump and the system were determined in the range of 3.1–4.8 and 2.1–3.1, respectively. The values of solar radiation, external temperature, relative humidity and wind speed were measured continuously. The relations of performance coefficients of ground source heat pump according to the meteorological data including solar radiation, wind speed, relative humidity and external temperature with this experiment were revealed exactly. The results of this study fulfil the lack in the literature.

Etude expérimentale sur la performance en refroidissement d'un système avec pompe à chaleur sol-eau

Mots clés : Sol-eau ; Pompe à chaleur ; Echangeur de chaleur ; Forage ; Sol ; Conductivité thermique

1. Introduction

In this study the characteristics of ground source heat pump located in Denizli were determined. Ground source heat pump systems are one of the environment-friendly systems used in the world for long years. High initial investment cost limits the installation of these systems. It is expected that the increase in energy costs and the obligation of decreasing greenhouse gases will increase the interest on these systems. The most important part of the system's cost occurs in ground heat exchanger and its installation. Ground heat exchangers can be placed 1–1.5 m under the ground horizontally and also they can be placed vertically by opening borehole until 200 m depth (Esen et al., 2007a,b).

In ground source heat pumps, drilling depth is very important in vertical installation because it is directly related to initial

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Nomenclature

T	temperature, °C
c	specific heat capacity, kJ kg^{-1} °k^{-1}
COP_{hp}	performance coefficient of ground source heat pump
COP_{sys}	performance coefficient of system
Q	amount of the heat transferred, W
$\dot{m}_w$	mass flow rate of water, kg s^{-1}
λ	thermal conductivity, W m^{-1} °k^{-1}
R	experimental result
w	total uncertainty
W	power, kW
W_c	power of compressor, kW
W_{cp1}	power of circulating pump of ground coupling circuit, kW
W_{cp2}	power of circulating pump of fan-coil circuit, kW
W_{fan}	power of fan, kW
x	independent variable

Subscripts

o	outlet
i	inlet
sys	system
hp	heat pump
c	compressor
cp	circulating pump
fc	fan-coil
g	ground
w	water

investment cost. So, thermal characteristics of the ground should be well known. To determine the change in ground temperature and thermal conductivity is very important for the installation of this kind of systems and for previewing their cost. In literature, there are many experimental and theoretical studies concerning ground source heat pump. As an example of these studies, Badescu (2007) presented the economic comparison of ground source heat pump with petroleum, natural gas and electricity. Esen et al. (2006) has reported a detailed techno-economic analysis of a ground source heat pump system and six conventional heating systems for the climate conditions of Turkey in heating season of 2002–2003. In hot climates such as in Turkey, GCHPs represent a viable alternative to ACHPs and conventional space cooling and heating systems because of their higher operating efficiency, especially during the cooling season. Akpinar and Hepbasli (2007) studied on exergy analysis of geothermal heat pump working with geothermal source in low temperature in AtatürkUniversity in Erzurum, Turkey and vertical ground source heat pump in Solar Energy Institute of Ege University in İzmir, Turkey. Michopoulos et al. (2007) used the GSHP system in heating and cooling seasons between 2003 and 2005 years. They measured ground temperatures and calculated the COP values and energy consumption. They stated that COP values of the system continuously increased during these 3 years. Hepbasli and Balta (2007) studied on the performance analysis of heat pump system which used a geothermal source. They made energy and exergy analysis and determined that the COP value of heat pump varied between 2.2 and 2.8. Omer (2008) emphasized in the study that ground source heat pump systems have been used in North America, Europe and many places of the world for long years. It is stated that GSHP system's cost is more than conventional systems; however, they have very low maintenance costs, reliable and they are environmentally friendly systems. In his study, moreover CO_2 emissions and energy efficiencies of conventional systems and ground source heat pump system were compared. In the study of Fan et al. (2007) examined the effect of underground water flow on ground heat exchanger's performance. It is stated that both in heating period and also in cooling period, underground water flow enhances heat transfer. Esen et al. (2007a,b), in their studies, examined energy and exergy analysis of a GCHP system with two different horizontal GHEs. Florides and Kalogirou (2007), in their studies, introduced various ground heat exchanger types and gave examples from the studies being made. Balta et al. (2008) theoretically studied on energy and exergy analyses for a room heated by a geothermal heat pump. Demir et al. (2009) used ground source heat pump in their study and placed the heat exchanger horizontally at 1.8 m depth. They determined ground temperature distribution and temperature values of inlet and outlet fluid of the ground heat exchanger from their theoretical and experimental studies. In Cyprus, Florides and Kalogirou (2008) stated a ground heat exchanger could be used to determine the heat extraction from ground or heat injection to ground and theoretically determined the characteristic (thermal conductivity and temperature of the ground) of borehole in their study. Esen et al. (2008) studied on the applicability of ANFISs to predict performance of a horizontal GCHP with R-22 as the refrigerant for a heating mode. Urchueguia et al. (2008) reported a direct comparison between a ground coupled and an air to water heat pump systems for heating and cooling in typical conditions of the European Mediterranean coast. Doherty et al. (2004) compared the heating and cooling performances of ground source heat pump system which had the three different types of the ground heat exchangers such as the vertical ground loop, the horizontal slinky loop, and the tank coil loop. Healy and Ugursal (1997) reported the optimal performance conditions of ground source heat pump system based on laboratory scale or residential house scale tests. In these small scales or applications, they set the components of ground source heat pump system such as compressors, heat exchangers, and pumps. Therefore, the COP of ground source heat pump system, and then they suggested that the several important design practices must be taken into account to achieve the higher performance. Popiel et al. (2001) presented the temperature distributions measured in the ground for the period between summer 1999 and spring 2001. The investigation was carried out in Poznan, Poland, for two differently covered ground surfaces, a bare surface and a surface covered with short grass. Temperatures were measured with thermocouples distributed in the ground at a depth from 0 to 7 m (bare surface) and from 0 to 17 m (short grass). Petit and Meyer (1997) presented a techno-economic analysis comparison of