Experimental investigation of the performance of a horizontal ground source heat pump

Mustafa Caner, Netice Duman, Ertan Buyruk, Ferhat Kılınç

Abstract— Efficient systems or using of renewable energy sources are intensely important for air conditioning. One of these systems is heat pump systems which uses energy in the nature as well. In this study, performance of ground source heat pump (GSHP) was investigated in province of Sivas, Turkey. For this aim, horizontal type ground source heat pump system was set up in energy home located in Cumhuriyet University campus in Sivas, Turkey. Underground heat exchanger composed of four lines with a total length of 370 m was placed in 2.5 m deep. The study discusses the soil temperature variations, variation of performance coefficients of heat pump and system with variation of inner and outer environment temperatures. The performance coefficients of heat pump and system were obtained in the range value of 2.18-2.05 and 1.90-1.76, respectively.

Index Terms— Ground source heat pump, space heating, coefficients of performance, renewable energy, heat exchanger, winter season, soil temperature distribution.

1 Introduction

Heat pump systems, which are considered to be environmentally friendly and have become widespread in recent years, set light to energy requirements as a solution method [1]. These systems use the renewable energy that is obtained from the environment. Solar energy which is stored under the ground, underground water and air during the year is converted into heating energy by means of electric energy [2].

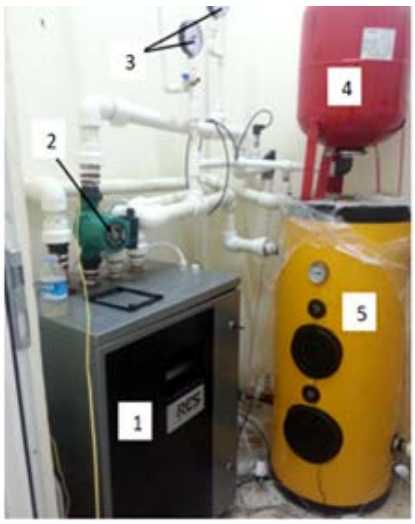
Heat pumps are defined as systems that carry the heat energy from low to high temperatures by using electrical energy. The low temperature is considered as the heat source. Air, water and soil may be used as a source in heat pumps. The performance of the heat pump is directly dependent on the source and the stability of the temperature.

Tarnawski et al. [3] performed to analyze a horizontal ground source heat pump system for 200 m² area in Japan and simulated the system on the computer simulation. As a result, the systems were found to be particularly useful in agricultural areas. Ozyurt and Ekinci [4] investigated the experimental performance of a vertical ground source heat pump at a depth of 53 m. The Coefficient of Performance (COP) values of the system ranged from 2.07 to 3.04. The results show that the system could be used for heating in the regions of Turkey with harsh climate. Naili et al. [5] investigated the performance of ground source heat pump for cooling application in Tunisia. The room where the experiments were made had a roughly floor area of 12 m². The COP values obtained show that the ground source heat pump system is suitable for cooling the region heat pump used. Mao and Chan [6] established a ground source heat pump system at 16 kW power. During the experiments, COP values were calculated between 1.56 and 2.01.

To this end, it is obvious that COP values of the ground source heat pump system underline that the system is a good alternate of electrical energy. However, there are some experiments settled in different regions of Turkey (e.g., [7]-[9]), no scientific research is made in Sivas. Sivas is known with the harsh climate conditions. It may distract the researchers to settle an experiment in Sivas. Towards this end, the study is organized to discuss the findings of experiments made to investigate the performance of the ground source heat pump system in Sivas. Therefore, the study is attached great significance that the ground source heat pump system was first tried in Sivas. Hereinafter, the study is organized as following. Following section informs on the experimental setup. Performance of the ground source heat pump is discussed in the next section. We conclude the study with some discussions on the findings.

2 Experimental Setup

In this study, the performance of the ground source heat pump (GSHP) is investigated in Sivas, Turkey. For this experimental project, a GSHP system was installed in Sivas Cumhuriyet University. The GSHP was used to heating a building with the area of 30 m². The system is shown in Fig. 1 while Fig. 2 shows a flowchart diagram of the GSHP system.



1	Heat pump
2	Circulating pump
3	Manometer
4	Expansion tank
5	Accumulation tank

Fig. 1. The GSHP system

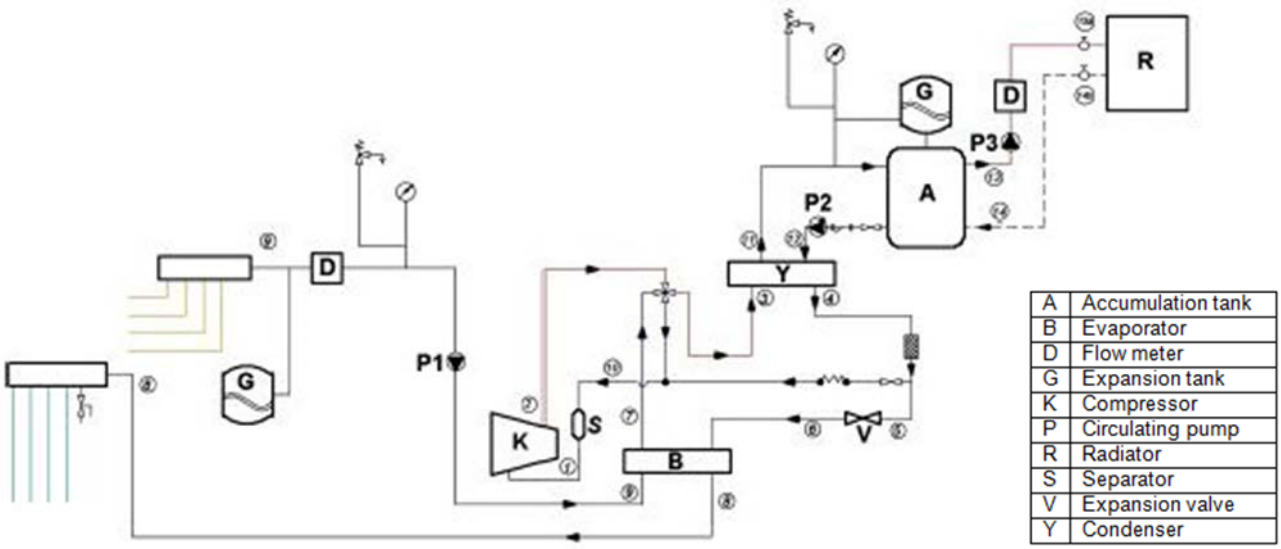


Fig. 2. The flowchart diagram of the GSHP system

As shown in Figure 2, the system consists of an underground heat exchanger, a collector, a distributor, a heat pump unit, pipelines, an accumulation tank, a circulation pump, and radiators. The stages of placing the ground heat exchanger at a depth of 2.5 m. are shown in Fig. 3. In addition, Fig. 4 shows the levels of depths of the thermocouples placed in the soil.

Fig. 3. Stages of placing the ground heat exchanger

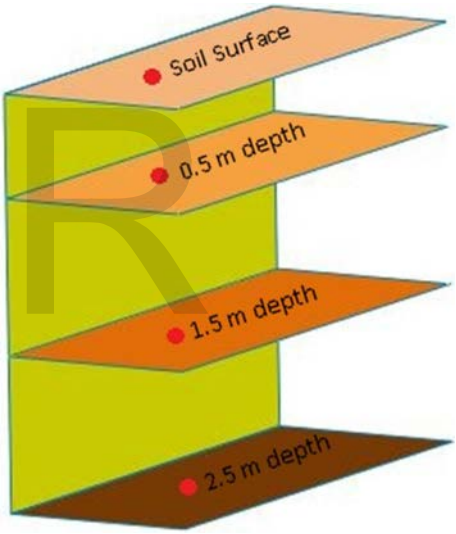


Fig. 4. Buried depths of the thermocouples placed in the soil.

A datalogger with 20 channels (±1 °C accuracy) was used to record the temperature measurements. The temperature of the heating water was measured by an ultrasonic thermal energy meter (%2-3 °C accuracy). The power measurements were measured by the electrical network analyzer (1% accuracy). All these measurements were recorded every minute.

3 Performance of the Ground Source Heat Pump

Experimental results obtained for one week (12 December 2016 – 17 December 2016) were used to show the performance of the GSHP system. The outdoor temperature was generally below 0 °C during the week and the average

temperature was -4.76 °C. Furthermore, the average indoor temperature was 23.63 °C. Fig. 5 shows the daily average values of indoor and outdoor temperatures.

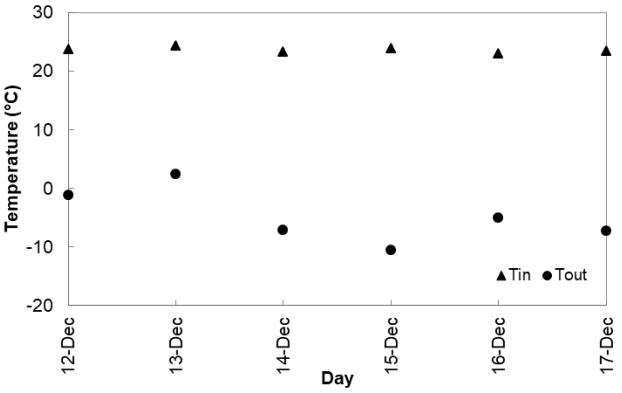


Fig. 5. Daily average values of indoor and outdoor temperatures

Figure 6 shows the variation of soil temperatures at different depths. In heating mode, the system draws heat from the soil. For this reason, the operation of the system reduces the soil temperatures. At the end of one week the temperature of the soil decreased by about 1 ° C.

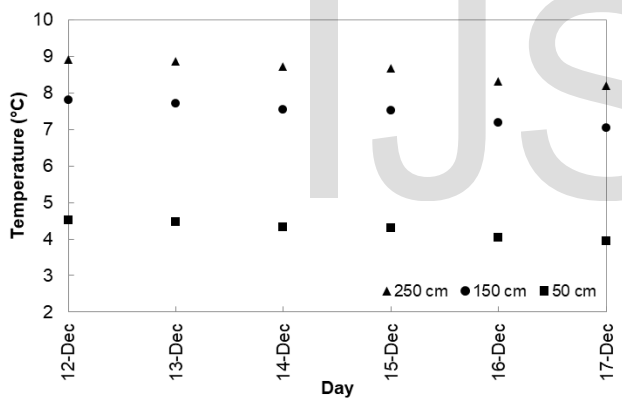


Fig. 6. The variation of soil temperatures

COP_{hp} and COP_{sys} values are given in Fig. 7. The performance coefficients of the heat pump and the system were changed between 2.05 and 2.18 and 1.76 and 1.90, respectively. The weekly averages were calculated as 2.08 and 1.81.

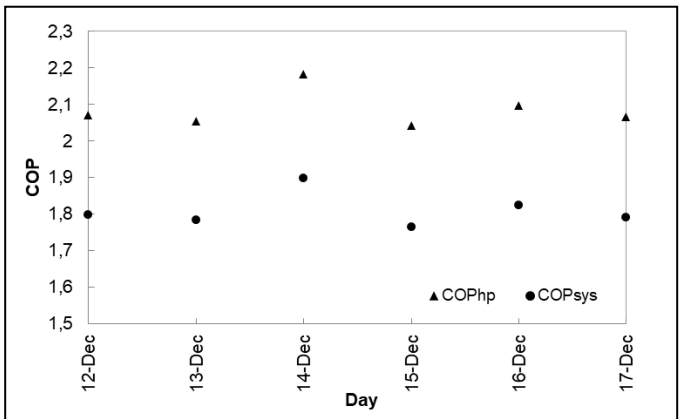


Fig. 7. COP_{hp} and COP_{sys} values

4 Conclusion

In addition to using renewable energy sources, heat pumps are important systems for air conditioning because they are environmentally friendly. To this sense, several studies have been done for the use of ground source heat pump in Turkey [7]-[9]. However, this is the first study made in Sivas. In the study, the following main conclusions were reached:

- Due to continuous heat extraction from the soil, soil temperatures have decreased over time. The highest value of heat extraction from the soil was 4.38 kW and the lowest value was 4.12 kW.
- As the heat extraction from the soil increases, the performance coefficient of the heat pump increases.
- As long as the system is operated, the average performance coefficient of the heat pump was 2.08 and the average performance coefficient of the system was 1.81. These values are similar to the values obtained in previous studies for harsh climate regions.

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