Journal of Advanced Engineering Trends
ISSN : 2682 - 2091

Vol.43, No.2. July 2024

http://jaet.journals.ekb.eg

"Using Hybrid Nanofluids to Improve the Performance of Flat Plate Solar Hot Water System"

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Abstract

The aim of the present study was to investigate how incorporating nanofluids affects the operational performance of a locally fabricated solar water heater's solar collector. To this end, three distinct nanofluids were created by mixing Al_2O_3, CuO, and SiO_2 within water a 0.5 volume percent ratio. The experiments were conducted at a location in upper Egypt, using two different flow rates, (0.0256) and (0.0423) kg.sec^{-1}. Results indicated that employing a mixed nanofluid instead of only water to circulate in the solar water heater panel tubes improved performance. Water temperature at the outlet and overall efficiency of the system were found to be better when the hybrid nanofluid is employed. The flow rate of the hybrid nanofluid was chosen at 0.0256 kg.sec-1 to produce the greatest improvement. The study provides evidence for the potential of nanofluids in enhancing the output temperature and thermal efficiency of solar energy collecting devices. This research offers valuable insights into the development of more efficient and sustainable energy solutions for the future. The use of nanofluids in FPSHs can lead to significant improvements in their performance, which has the potential to positively impact the energy sector.

keywords

Nanofluids, locally fabricated solar plate collector, Nano Alumina, CuO, SiO_2, Blended nanofluid, flow rate, outlet water temperature, overall efficiency, thermal efficiency, solar energy collector.

Revised: 26 March, 2023, Accepted: 11 June , 2023

1. Introduction

Solar energy has surged in popularity as a sustainable energy source in recent years[1]. One of the most effective ways to use solar energy is to use water heaters that are based on solar collectors. [2,3]. The extraction of solar energy requires the use of a solar thermal collection system since it converts light into heat. To optimize the thermal energy acquired from the sun, the working fluid's thermal characteristics can be improved. Most frequently in household settings for washing and bathing needs, Solar water heaters are extensively employed for heating requirements of moderate intensity [4,5]. Typical solar collectors that operate with conventional heat-absorbing fluids often exhibit poor performance. However, replacing the circulating fluid in the solar panel of water heaters with nanofluids can enhance their efficiency [6]. In households all throughout the world, Solar hot water heaters are widely used to heat water at low temperatures. like bathing and washing clothing. The passive flow type solar water collector, which can produce boiling water at about 80°C, is a fundamental type of solar system. Another version, called an active solar water heater, is also available. It works by combining antifreeze with regular water to prevent pipe damage from water hypothermia in colder climates as well as salt precipitation on interior tubing surfaces [7,8]. Fluids made of nanoparticles have been created to increase the practical heat content of water in thermal systems and the efficiency of working fluids at transferring heat. This is accomplished by adding nanoscale particles to the working fluid that have significant thermal characteristics, increasing the fluid's rate of heat transmission. Nanoscale particles are used to overcome the drawbacks of conventional heat transfer fluids, which have poor heat conductivities and ineffectiveness un heat transfer apparatus [9,10]. Researchers from all around the world have extensively investigated the use of nanofluids in several home and industrial uses, both theoretically and experimentally [11,12] . Particle size, shape, fluidity, heat capacity, and pH are just a few of the variables that affect how well nanofluids transport heat. Numerous techniques have been suggested to investigate the behaviour of nanoparticles in various environments. The use of nanofluids as heat transfer fluids is a relatively new field that has only just begun to take off. Nanofluids are liquids with suspended solid particles in the nanoscale size range. However, studies have demonstrated that nanofluids often increase the effectiveness of heat transfer [13,14]. It has been demonstrated that nanofluids can improve heat exchanger efficiency by consuming less energy. The thermal conductivity of these fluids is potentially three times greater than that of conventional fluids, allowing them to boost heat transfer rates by a factor of four without having to use more power from the pumps. The term "nanofluid" refers to a liquid containing metal and ceramic particles suspended at the nanoscale. Because metal and ceramic particles often have better thermal properties than other types of particles, nanofluids are renowned for having a large increase in heat capacity, fluidity, and heat transfer rate when compared to ordinary liquids [15]. Researchers have previously looked at adding nanoscale metal oxide particles to a working fluid to increase thermal conductance. In their experiments, Masuda et al. [16] found an improvement of about 20%. He et al. [17] looked into how copper oxide (CuO) based nanofluids the study investigated the impact of nanofluids on the functioning of solar heater and observed a significant improvement in efficiency. Similar results were achieved by Yousefi et al. [18] who used alumina-based nanofluids on FPSH solar collectors and discovered a 28.3% improvement in efficiency. The main objective of this study is to assess the impact of incorporating a mixed nanofluid consisting of same amounts of SiO_2, Al_2O_3, and CuO particles (at the nanoscale) as a heat absorber fluid on the thermal performance of solar water heater (passive type). The solar water heater has a collector area of 2.2 m^2 and the pipes inside the collector have a diameter of 1.3 cm. The research was conducted in Upper Egypt in August 2021 and investigated the effects of two different mass flow rates on the system's performance. The study primarily aims to determine how the use of a secondary fluid affects the thermal efficiency of the system.

2. Experimental setup

The solar water heater utilized in the present study was assembled locally using cost-effective parts and features a passive flow system, as shown in figure 1. The collector had dimensions of 1500mm long by 750mm wide, and it was attached to a 75L capacity cylindrical tank. The hybrid nanofluid used in this study was designed to flow through the solar collector to absorb heat and then circulate through serpentine copper tubes in a secondary tank located inside the main water tank. The heated nanofluid is then transferred to the water in the main tank, as it circulates through the serpentine tubes in the secondary tank. No pumping was necessary to move the nanofluid from the bottom line of the solar collector to the top line of the solar collector thanks to thermosyphonic action, as shown in figure 2. Heat from the collector was collected by the circulating nanofluid and transmitted to the water inside the tank. Except for the top face, which was sealed with a glass cover with high transmittance, the absorber was wrapped in 50mm glass wool insulation on all sides. In order to minimize heat loss, glass wool insulation was also placed around the external water tank. To maximize solar energy, the FPSH was set up with its south facing tilt at a 33° [19-21]. Water and surrounding-area temperatures were measured using J-type thermocouples and presented on a digital indicator.

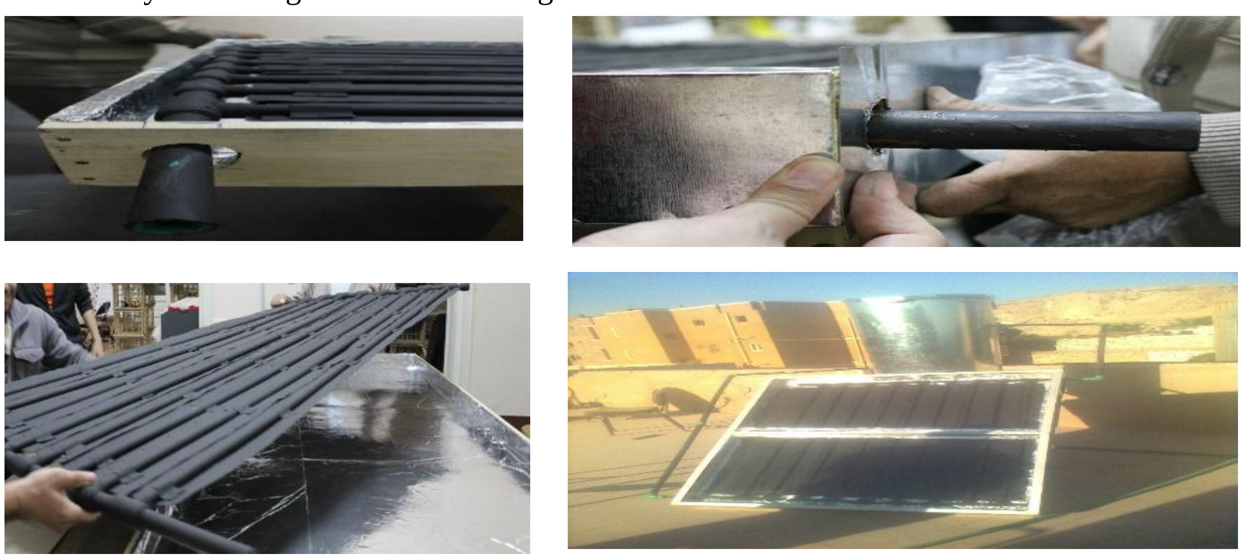

Fig.1 Solar water panel

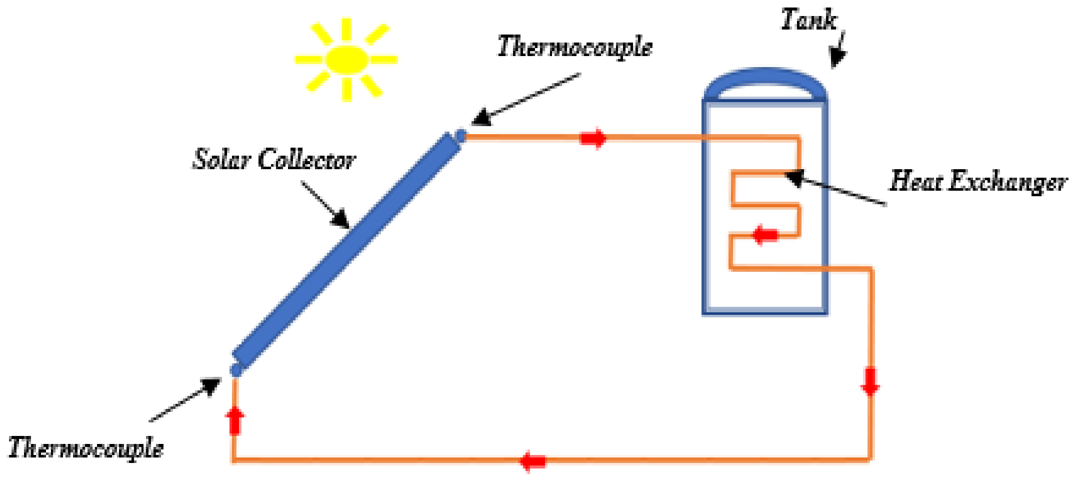

Fig.2 Schematic diagram of locally fabricated solar water heater

3. Nanofluid Preparation

We obtained 99.5% pure Al2O3, CuO, and SiO_2 nanoparticles with a 40 nm particle diameter. from reliable chemical sources. To serve as a surfactant, we also purchased sodium dodecyl sulphate (SDS), which we used to assure the consistency and stability of our hybrid nanofluid across many cycles of operation. We painstakingly measured each type of nanoparticle using a precise physical balance to create the nanofluid, which included 0.5% of each type in total. The foundation fluid was high quality water. Using a magnetic stirrer for 40 minutes, The CuO, Al_2O_3, and SiO_2 nanoparticles were mixed with a solution of Sodium Dodecyl Sulfate, which was used as a stabilizing agent to guarantee that the base liquid and nanoparticles are thoroughly mixed, the nanoparticle solution was combined with filtered water, creating a nanofluid. This mixing process took 120 minutes. Once created, the nanofluid was then transferred to a separate tank for further use in the experiment.

4. Testing Method

The aim of the study was to investigate the effect of a hybrid nanofluid on the performance of a water solar collector. The study was conducted using two different mass flow rates specifically 0.0256 and 0.0423 kg.sec^{-1}, being tested, to ensure accurate control of the nanofluid flow, a flow restrictor was installed in the secondary circulation circuit. This was done to regulate the flow rate and maintain consistency in the experiment. The experiments were conducted using two sets of ordinary water as the secondary heat transfer fluid and two sets of the hybrid nanofluid. The tests were carried out between 10:00 am and 5:00 pm to simulate typical operating conditions for a solar water heater. during daylight hours, with temperature measurements made using thermocouples and real-time solar radiation data captured using a solar power meter. The gathered information was utilized to assess the system's performance.

The energy production was determined using a number of variables, including the mass flow rate. The computation procedure is as follows::

Energy Output = ṁ * Cp * (To - Ti) ….. (1)

Where:

ṁ = mass flow rate of the working fluid (kg/s)

Cp = heat capacity of the working fluid (J/kg K),

T_o = outlet temperatures of the solar collector (K),

T_i = inlet temperatures of the solar collector (K),

A = surface area of collector (m^2).

The Energy Input was calculated using the solar radiation magnitude on the solar collector:

Energy Input = A * GT ……………(2)

Where:

GT = The solar collector's exposure to sun radiation(watt/m^2),

5. Results and Discussion

The experiments were conducted under two different conditions from 10:00 am to 5:00 pm. In each condition, two different secondary heat transfer fluids were used, with one set using hybrid nanofluids under different flow rates of 0.0256 kg.sec^{-1} and 0.0423 kg.sec^{-1}, and the other set using traditional filtered water. Temperature measurements were taken and analyzed hourly throughout the experiments.

The solar radiation schedule for the inquiry days is depicted in Figure 3. It appears that the solar radiation has remained constant over the course of the inquiry, proving that the trials were conducted under similar circumstances. The average amount of solar radiation measured was 730 W/m^2. The ambient temperature recorded during the experiments under different scenarios is depicted in Figure 4. The measured ambient temperature was 34 degrees Celsius. The change in temperature between the inlet and outlet water for each of the four cases is presented in Figure 5. Midday, when the sun was at its brightest, was when the temperature gradient was at its greatest. In the morning and evening, there was less of a temperature difference. The temperature gradient was shown to be significantly influenced by the flow rate, 0.0256 kg.sec^{-1} being the flow rate with the highest temperature gradient. There was a 39.6% and a 29.5% rise in temperature gradient when employing flow rates of 0.0256 kg/sec-1 and 0.0423 kg.sec^{-1}, respectively. This demonstrates how hybrid nanofluids could improve the basic fluid's temperature gradient. The outcomes in Fig. 6 show how the solar water system performs when purified water and nanofluid are used at various flow rates. Equations (1), and (2) were used to determine the system's effectiveness, which is depicted in Fig. 6. The system's effectiveness decreased as the flow rate increased. When the sun's incident energy was at its greatest during noon, the highest immediate efficacy was attained. With a flow rate of 0.0256 kg sec^{-1}, the hybrid nanofluid system demonstrated the highest efficacy. At flow rates of 0.0256 and 0.0423 kg.sec^{-1}, the hybrid nanofluid was found to be 46.4% and 34.9% more effective than regular water in the system.

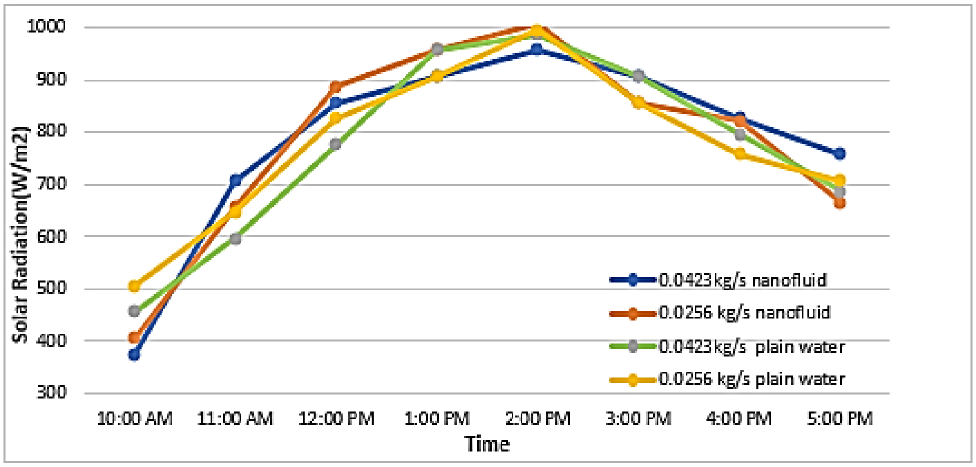

Fig.3 Solar Insolation Variation During the Experiments

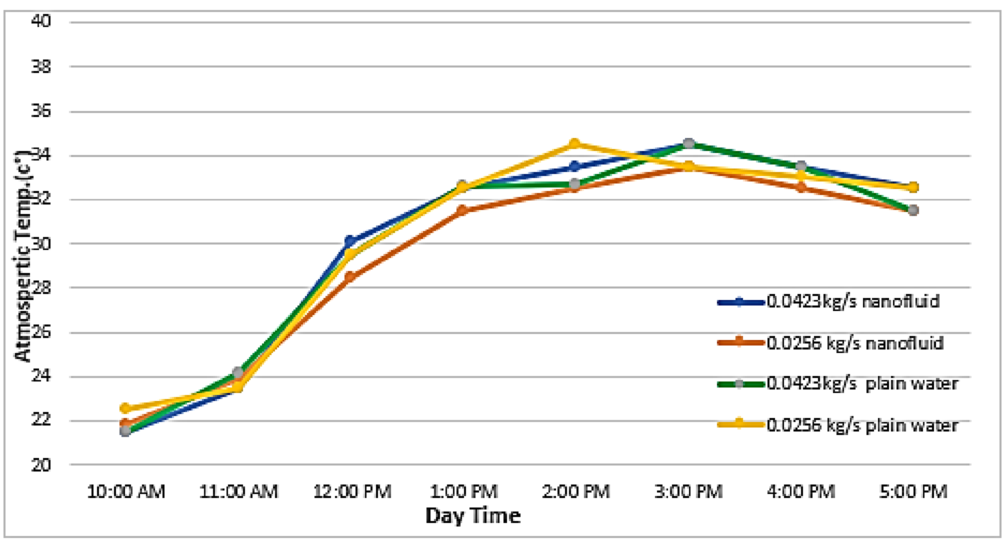

Fig.4 Temperature of the Ambient Air During the Experimental Study

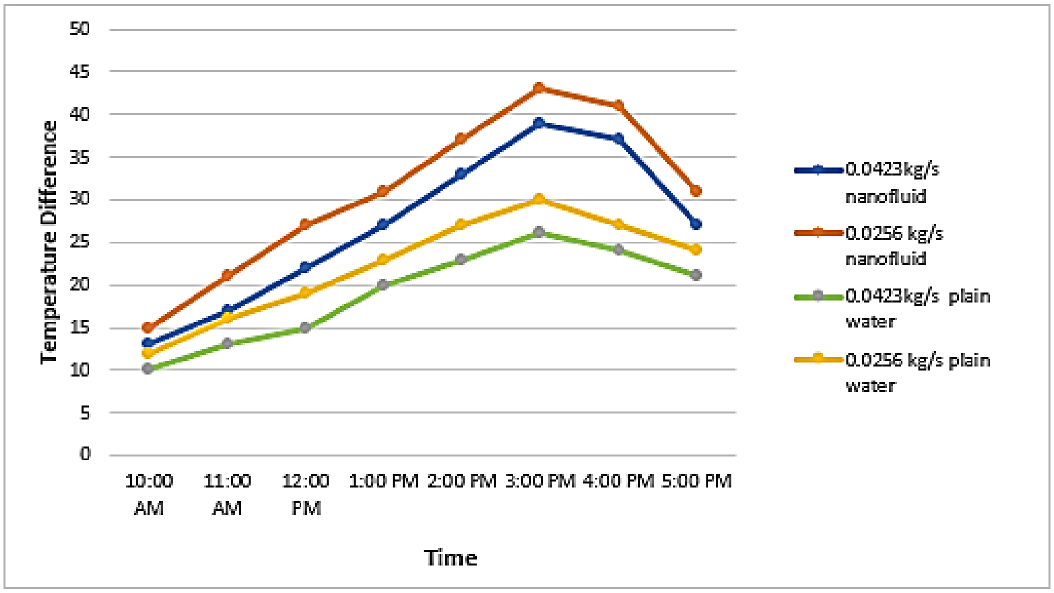

Fig.5 Temperature variation throughout the experiment

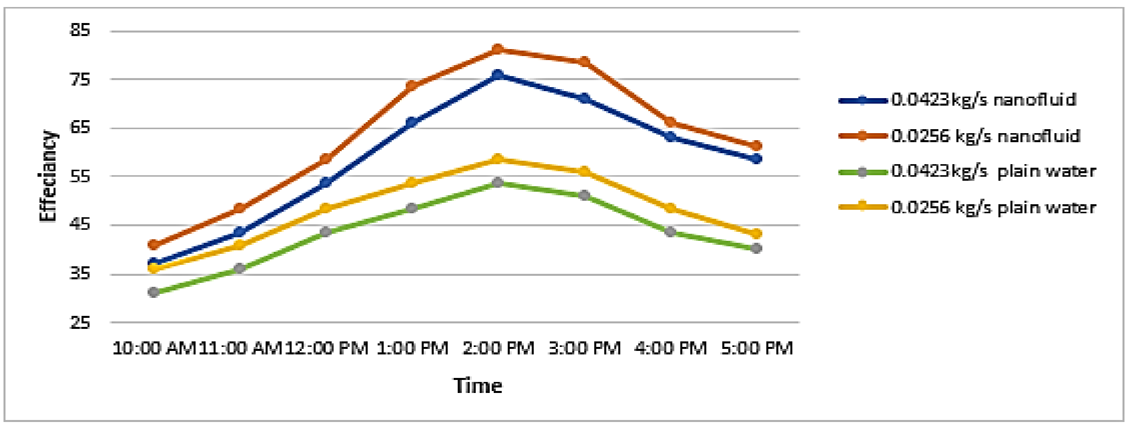

Fig. 6: System efficiency during experimentation

6. Conclusions

In this study, the impacts of using a hybrid nanofluid comprising CuO, Al2O3, and SiO2 as the heat transfer medium on a solar water heater system were examined. The outcomes demonstrated that the flow rate has a significant impact on the heating system's performance, with 0.0256 kg/sec offering the greatest results. The hybrid nanofluid enhanced the system's temperature differential by 39.6% and 29.5% as compared to using plain water at flow rates of 0.0256 and 0.0423 kg/sec, respectively. Switching from ordinary water to a hybrid nanofluid increased system efficiency by 46.4% and 34.9% at the same flow rates.

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