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Effect of titanium dioxide/water nanofluid use on thermal performance of the flat plate solar collector

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A R T I C L E I N F O

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A B S T R A C T

In this study, the effect of using of titanium dioxide-water (TiO_2/water) nanofluid on the performance of the flat plate solar collector (FPSC) has been experimentally investigated. The nanofluid was obtained by mixed with a 2 wt% TiO_2/pure water mixture. In order to maintain the stability of the prepared nanofluid suspension and to eliminate the problem of agglomeration over time, 0.2 wt% Triton X-100 surfactant was added into the mixture. The nanofluid was mixed in continuous pulsing for 8 h in ultrasonic bath. In the experiments done in accordance with EN ISO 9806 standard, the highest instantaneous enhancements for pure water and nanofluid was determined and the results were provided by graphical representations comparatively. In the experimental flat plate solar collector setup, the highest instantaneous efficiency was obtained to be 48.67% for TiO_2/water nanofluid, whereas the highest instantaneous efficiency was 36.20% for pure water.

1. Introduction

In recent years, due to the limitations of energy resources, there has been a serious increase in the interest of renewable energy sources in all the countries of the world. One of the most important renewable energy sources is solar energy and its application area has come into prominence as solar collector hot water providing systems. However, the low efficiency of solar collectors is one of the major disadvantages of solar energy hot water preparation systems. Due to this problem, enhancing efficiency in solar collectors has been an accentuated working area these days.

Working fluid is one of the most critical parameters that affects thermal performance of flat plate solar collectors. Thermal conductivity and heat transfer performance are the leading factors that make working fluid (generally water and antifreeze water) important. The use of nanoparticles and nanofluid has been one of the high-tech methods in enhancing the efficiency in solar collectors. With the improvements in material technology in recent years, to get high performance nanofluid has been possible (enabled). The nanofluid have been prepared by adding nano-sized metallic particles which have high thermal conductivity, into the traditional thermal transfer fluids. Basic physical facts that cause a considerable improvement in nanofluid heat transfer enhancement have been listed below:

- The increase in thermal conductivity as a result of nanosized solid metals which has been added into basic fluids as suspension since the thermal conductivity of solid metal is higher than base fluid.
- The increase in thermal conductivity of the fluid because of the increase in thermal transfer surface area.
- The increase in effective thermal capacity of the fluid.
- The increase in thermal conductivity of the fluid due to high fluid activity and turbulence volume

Studies in literature were generally related to the thermo-physical properties (Das et al., 2003; Patel et al., 2003; Mahian et al., 2013; Xuan and Li, 2003) of different types of nanofluids (Lee et al., 1999; Zamzamian et al., 2014; Eastman et al., 1997; Qinbo et al., 2015) and their performances on thermal systems especially in heating pipes (Sözen et al., 2016a,b), there was little research into, nanofluid use in solar collectors. Yousefi et al. (2012a) experimentally studied the method of changing pH using nanofluids containing 0.2% wt. MWCNT (multi-walled carbon nanotubes) in flat plate solar collectors. They have showed that the current nanofluid increased the performance of the collector and this increase was much higher at low heat. In another study by Yousefi et al. (2012b), the nanofluid containing 2 wt% alumina particles have been tried a by mass and Triton X-100 surface activator in flat plate solar collectors. The mass flow of the nanofluid was kept in the range of 1–3 L/min. In the result of these experiments it was seen that nanofluid collector efficiency increased 28.3%. Lu et al. (2011) studied the effects of the use of nanofluids containing different

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Nomenclature

Symbols

$\dot{Q}$	useful power extracted from collector [W]
$\dot{m}$	mass flow rate of heat transfer fluid [kg/s]
cp	specific heat capacity of heat transfer fluid [J/kg K]
ΔT	temperature difference between fluid outlet and inlet (Te-Tin) [K],
A_G	gross area of collector [m^2]
η_{hem}	collector efficiency
G	radiation intensity [W/m^2]
T^*_m	reduced temperature difference [m^2K/W]
t_m	mean fluid temperature [K]
T_{in}	collector inlet temperature [K]
T_e	collector outlet (exit) temperature [K]
T_a	temperature ambiance [K]
Ws	total uncertainty
W1	total fault coming out in flowrate measurement
W2	total fault coming out in temperature measurement
W3	fault in pyranometer and radiation measurement
W4	fault in thermocouple and temperature measurement
W5	total fault in air velocity measurement

Abbreviations

ASHRAE	American society of heating refrigerating and air-conditioning engineers
CFD	Computational Fluent Dynamic
DLS	Dynamic Light Scattering
FPSC	Flat Plate Solar Collector
ISO	International Organization for Standardization

rate of CuO particles for vacuum tube solar collectors on thermal performance. In the experiments conducted, 1.2 wt% CuO nanoparticle-water concentration was found to provide the best thermal transfer enhancement. Nagarajan et al. (2014) made a comprehensive compilation about nanofluids in solar collector use and thermo-physical properties of nanofluids.

This study aims to investigate the effect of TiO_2/water nanofluid use on flat plate solar collector. The most basic characteristic of TiO_2 is that the water absorption ability is high and therefore the high gelling occurs with high lubrication. With this feature, the problem of precipitation of nanofluids has not been considered during the experiment and the fluid stability has been maintained. In addition, the pressure loss caused by the gelation and nanofluids is minimal and remains negligible. The most important feature that differentiates this study from the literature is that a suitable fluid is obtained to improve the thermal performance of the working fluid, which is one of the passive performance increasing methods in thermal systems. In order to determine the effect of TiO_2/water nanofluid use on performance, experiments were conducted with pure water and TiO_2/water nanofluid separately and the results were comparatively discussed.

2. Experimental setup

The experimental setup is prepared according to EN ISO 9806 standard (European Norm EN ISO 9806, 2013) (Fig. 1). The tests were carried out under the under EN ISO 9806. To be able to make a

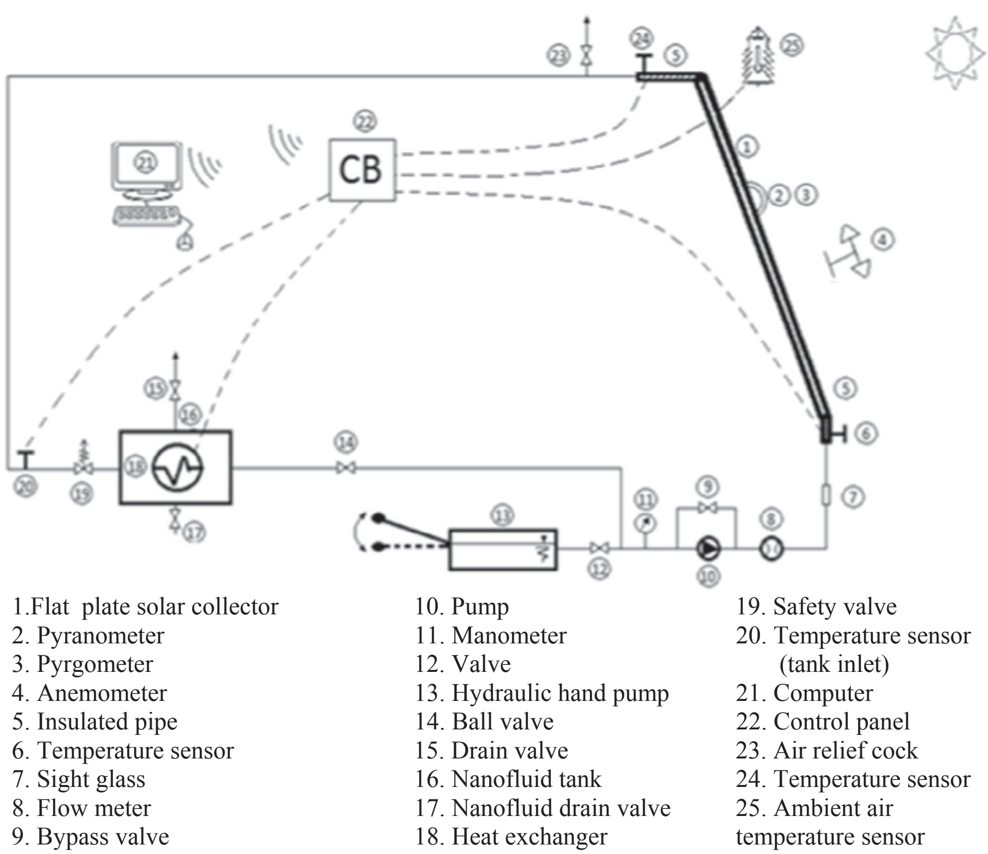

Fig. 1. Schematic of experimental setup.