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Investigation of TiO_2 and MWCNT Nanofluids-based Photovoltaic-Thermal (PV/T) System

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Abstract
Nanofluids as a new generation of cooling fluid has been found in recent years to improve the heat-transfer coefficient and enhance the system performance. This study presents investigation conducted on the performances of TiO_2 and MWCNT nanofluids-based PVT systems. The preparation of nanofluids using two step method and dispersing of surfactant for a stable nanofluid. The experimental investigation with the effect of different concentration, mass flow rate (0.012 kg/s to 0.0255 kg/s) and solar radiation (500 W/m^2 to 900 W/m^2) on the performance of nanofluids-based PVT system is presented. The lowest temperature of the PV module and highest fluid's change of temperature were recorded when the collector uses TiO_2 fluid 1.0 wt% which is 2.01ºC and 1.80ºC.

Keywords: PV panel cooling, titania/water, nanofluid

1. Introduction
The efficiency of PV cell conversion from solar energy to electricity decreases as operating temperatures increase. Combining solar thermal collectors and PV cells in a system known as photovoltaic thermal (PVT) system can reduce the operating temperature and improve the system efficiency. PVT also produces thermal energy and thermal energy simultaneously. A PVT system consists of a PV panel, insulation and frame. Also, a PVT system is by using heat transfer area through the absorber with finned absorber, corrugated surfaces and porous media for improvement of collector's efficiency [1]–[2]. PVT systems using in various applications, such as air heating, solar cooling, solar drying, water heating and desalination. Exergy analysis is an essential tool in the system design, analysis and optimisation of thermal systems [3]–[11].

The PVT system can be classified into four types based on heat transfer medium, that are air based, water-based, the combination of air/water-based and nanofluid-based [12]. Different types of nanoparticles has been used to enhance the PVT's performances such as magnetic and carbon based nanoparticles [13-14]. Khanjari et al. [15] reported PVT, thermal and PV energy efficiencies of 90%, 55% and 10%–13.7%, respectively, and PVT exergy efficiency of 15%. Lari and Sahin [16] reported that 13.2% PV energy efficiency was achieved for a nanofluid-based PVT system.

In this present study, it focused on effects of mass flow rates and solar radiation in nanofluid-based PVT systems which discussed the effects of different volume concentration of nanofluids to the change in fluid temperature and the temperature of panel. The elaboration of results were focused on the radiation of 500 and 900 W/m$_2$ for each fluid test.

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2. Material and Methods

The setup of the PV/T system during the indoor experiment under solar simulator is shown in Figure 1. A 0.5x1.2 m of a standard polycrystalline 80 W photovoltaic module with a spiral absorber underneath the panel has been set up. K-type thermocouple with data logger was used to collect the change in temperature for inlet, outlet and the module's temperature, which data has been recorded in each 1 minute. The total incident radiation on the system was measured by a pyranometer. A flow meter (1–4 G/M) was mounted at the opening of fluid inlet to control the mass-flow rate. The experiment was conducted under an indoor testing facility by using a solar simulator controlled by a variable voltage controller. The PV/T system has been exposed to the solar-radiation 40 min before collecting the data to ensure the equilibrium state of radiation. The change of voltage was recorded using electric load under different mass flow rates and volume concentrations of the nanofluid.

The system temperature was measured from the thermocouple stored in the data logger for every 1 min and was later used to calculate the electrical and thermal efficiency for the collector. The fluid was circulated around the system by using the pump and heat exchanger utilised for cooling the fluid in the closed loop system.

(a) (b)

Figure 1. Setup of the nanofluids-based PV/T system under solar simulator: (a) top view of system, (b) top view of spiral absorber

3. Results and Discussion

The PVT system has been tested in the laboratory at various fluid flow rates of 0.012 kg/s to 0.0255 kg/s at different concentrations for nanofluids as has been mentioned previously. The influence of fluid flow rate coupled with the intensity of the modified radiation to compare the performance of the PVT system at different nanofluid concentrations.

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Figure 2 to Figure 4 shows the effects of fluid flow rate changes and nanofluid concentration on surface temperature at radiation 500 W/m^2, 700 W/m^2 and 900 W/m^2. PV surface temperature is lowered in every intensity of radiation when fluid flow rate increases. For the same fluid flow rate, the surface temperature of the PV module is higher at high intensity radiation. Based on Figures 2 to Figure 4, the fluid flow rate changed from 0.012 kg/s to 0.0255 kg/s, PV surface temperature for water decreased from 52.14 ℃ to 51.66 ℃ in intensity 500 W/m^2. When the intensity of the radiation is increased to 900 W/m^2 and the same range of fluid changes, the PV module surface temperature decreases from 71.60 ℃ to 70.72 ℃.

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While surface temperature PV module for TiO_2 nanofluid is 0.5 wt% where the temperature drops from 51.83 ℃ to 51.21 ℃ in the same fluid flow rate range below the 500 W/m^2 intensity. The surface temperature of the PV module then decreases from 69.55 ℃ to 67.54 ℃ when the intensity of radiation increases to 900 W/m^2. The surface temperature of the PV modules of the TiO_2 nanofluid flow 1.0 wt% recorded a reduction in surface temperature of the PV module recorded from 51.41 ℃ to 50.59 ℃ at 500 W/m^2 intensity and subsequently decreased from 68.40 ℃ to 66.90 ℃ when the intensity of the radiation was charged to 900 W/m^2.

The surface temperature reduction for MWCNT nanofluid is 0.02 wt% in the same fluid flow rate change from 52.07 °C to 51.43 °C at 400 W/m^2 and 70.24 ℃ to 68.76 ℃ at an intensity of 500 W/m^2 and 900 W/m^2. Finally, the decreased surface temperature of MWCNT nanofluid collector 0.1 wt% is recorded from 51.92 °C to 51.35 ℃ at 500 W/m^2 and when the intensity of the radiation changes to 900 W/m^2, the surface temperature decreases from 70.02 ℃ to 67.80 ℃.

The lowest temperature of the PV module is recorded when the collector uses TiO_2 fluid 1.0 wt% followed by TiO_2 0.5 wt%, CNT 0.1 wt%, CNT 0.02 wt% and water. Low fluid flow rates result in higher rising temperature of PV modules when radiation intensities are increased. The surface temperature of the PV module also increases when the intensity of radiation increases from 500 W/m^2 to 900 W/m^2. The decrement of PV surface temperature is higher with the deployment of nanofluid compared to the normal fluid and greater temperature dropped when higher concentrations had been used, showing ~~that~~ better efficiency gained by using nanofluid than water.

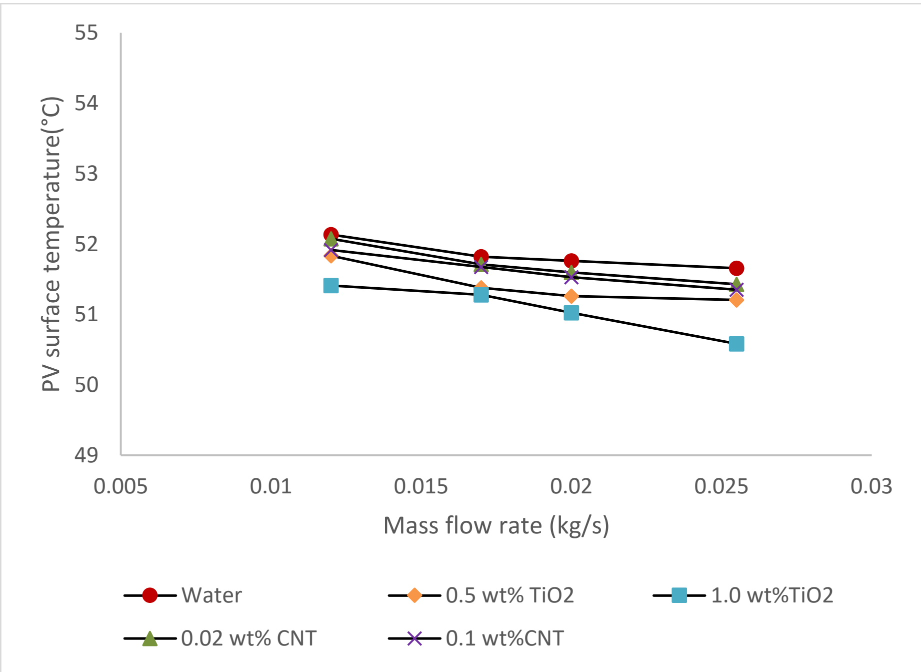

Figure 2. The effect of fluid flow rate and nanofluid concentration on surface temperature of PV module at intensity of 500 W/m^2

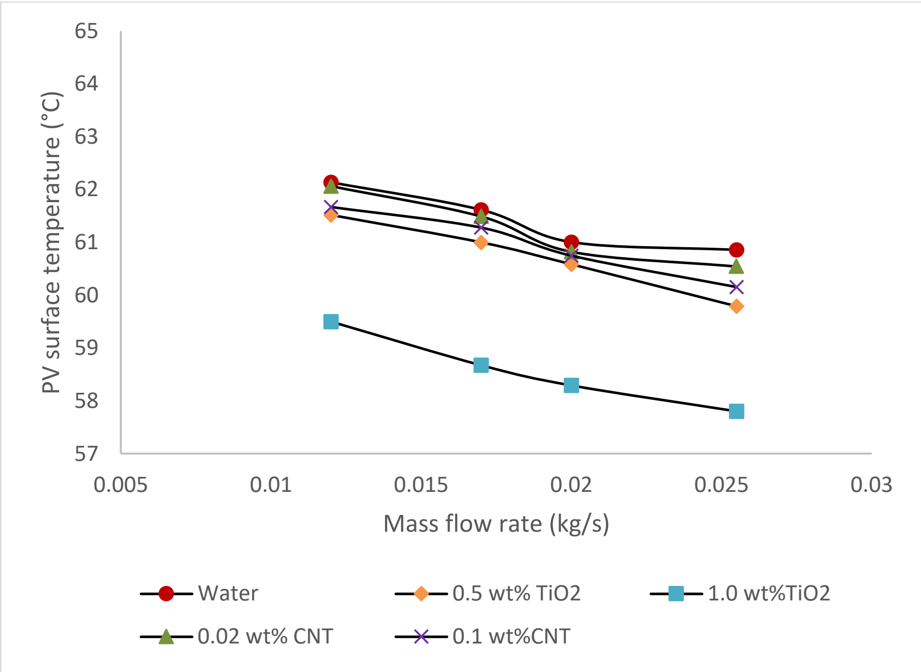

Figure 3. The effect of fluid flow rate and nanofluid concentration on surface temperature of PV module at intensity of 700 W/m^2

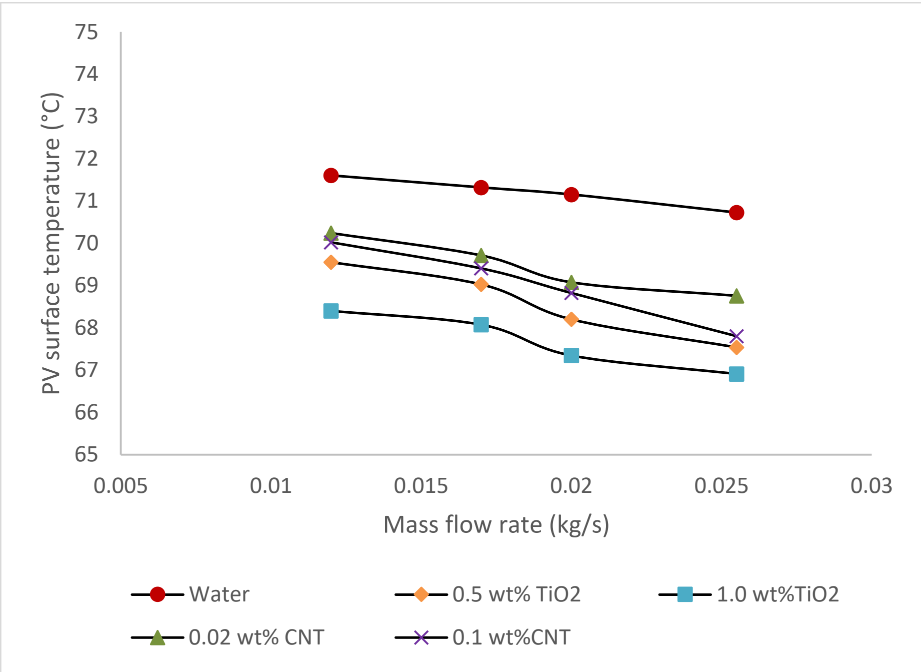

Figure 4. The effect of fluid flow rate and nanofluid concentration on surface temperature of PV module at intensity of 900 W/m^2

The second objective which to study the effects of using nanofluids on the change of fluid's temperature has been verified. The changes of fluid's temperature were obtained from the inlet, T_i and the outlet fluid, T_o. It has been shown that the change in fluid temperature is decreasing with the increase of fluid flow rate with increased concentration of nanofluid for all radiation intensities. PVT water collector recorded decrement from 3.39 ℃ to 1.82% ℃ Employment of 0.5 wt% of TiO_2 nanofluid had shown fluid temperature drop from 3.93wt% to 2.17wt% and 4.03wt% to 2.23wt% for 1.0 wt% of TiO_2.

Meanwhile, 0.02 wt% and 0.1 wt% nano fluid MWCNT recorded a temperature reduction from 3.52 ℃ to 1.96 ℃ and 3.77 ℃ to 2.09 ℃.

The increase in fluid temperature change is a parameter that directly affects the thermal efficiency of the PVT system. PVT systems operating with nanofluids provide greater temperature changes. This can be explained by the specific properties of specific heat capacity of nanofluid and water. The specific heat capacity of the nanofluid is lower than the specific heat capacity of the water. Consequently, when lower heat capacity is applied to the same intensity of solar radiation, a higher rise in temperature had been recorded. The highest fluid temperature change were recorded by TiO_2 1.0 wt% followed by fluid TiO_2 0.5 wt%, CNT 0.02 wt%, CNT 0.1 wt% and water.

4. Conclusions

This experimental investigation has been conducted in order to study the effect of utilizing different concentration of different coolants with varied mass flow rate (0.012 kg/s to 0.0255 kg/s) and solar radiation. The temperature of surface temperature correlated directly proportionally to the solar radiation upon the PV panel. All in all, it can be concluded that as the mass flow rate of the fluids regulated increase, the surface temperature of the PV module decrease for all type of utilized fluids which are water, TiO2 and MWCNT. Based on great decrement of surface PV's module temperature, nanofluids has been efficiently cooling down the PVT system than water.

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References

[1] Z. Xu and C. Kleinstreuer, Concetration photovoltaic-thermal energy co-generation system using nanofluids for cooling and heating,"Energy Conversion and Management. 2014; 87: 504-512.

[2] S.A. Kalogirou, S. Karellas, V. Badescu, K. Braimakis, Exergy analysis on solar thermal systems: a better understanding of their sustainability. Renewable Energy. 2016;85: 1328-1333.

[3] A. Fudholi, K. Sopian, B. Bakhtyar, M. Gabbasa, M.Y. Othman, M.H. Ruslan, Review of solar drying systems with air-based solar collectors in Malaysia. Renewable and Sustainable Energy Reviews. 2015; 51:1191-1204.

[4] A. Fudholi, K. Sopian, M. Gabbasa, B. Bakhtyar, M. Yahya, M.H. Ruslan, S. Mat, Techno-economic of solar drying systems with water based solar collectors in Malaysia: a review, Renewable and Sustainable Energy Reviews. 2015; 51: 809-820.

[5] M. Yahya, A. Fudholi, K. Sopian, Energy and exergy analyses of solar-assisted fluidized bed drying integrated with biomass furnace, Renewable Energy. 2017;105:22-29.

[6] Y.M. Xuan, W. Roetzel. Conception for heat transfer correlation of nanofluids. Internatuonal Journal of Heat and Mass Transfer. 2000; 43: 3701-3707.

[7] R.K. Mishra, G.N. Tiwari. Energy and exergy analysis of hybrid photovoltaic thermal water collector for constant collection temperature mode. Solar Energy. 2013; 90: 58-67.

[8] A. Fudholi, K. Sopian, R&D of photovoltaic thermal (PVT) systems: an overview. International Journal of Power Electronics and Drive Systems (IJPEDS). 2018; 9 (2), 803-810.

[9] A. Fudholi, M.H. Ruslan, M.Y. Othman, M. Yahya, A. Zaharim & K. Sopian. Collector efficiency of the double-pass solar air collectors with fins," Proceedings of the 9th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING (ICOSSSE'10), Japan, 2010, pp. 428-34.

[10] A. Fudholi, M.H. Ruslan, M.Y. Othman, M. Yahya, A. Zaharim & K. Sopian. Experimental study of the double-pass solar air collector with staggered fins," Proceedings of the 9th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING (ICOSSSE'10), Japan, 2010, pp. 410-14.

[11] A. Fudholi, K. Sopian, M.Y. Othman, M.H. Ruslan, B. Bakhtyar, Performance and cost benefits analysis of double-pass solar collector with and without fins, Energy Conversion and Management. 2013; 76:8-19.

[12] A. Fudholi, K. Sopian, M.Y. Othman, M.H. Ruslan, B. Bakhtyar, Energy analysis and improvement potential of finned double-pass solar collector, Energy Conversion and Management. 2013; 75:234-240.

[13] Al-Sharafi A, Sahin AZ, Yilbas BS. Measurement of thermal and electrical properties of multiwalled carbon nanotubes-water nanofluid. J Heat Transfer 2016; 138:72401

[14] Xu G, Zhao S, Zhang X, Zhou X. Experimental thermal evaluation of a novel solar collector using magnetic nano-particles. Energy Convers Manage 2016;130:252–9

[15] Khanjari, Y., Pourfayaz, F., & Kasaeian, A. B. Numerical investigation on using of nanofluid in a water-cooled photovoltaic thermal system. Energy Conversion and Management 2016, 122, 263-278.

[16] Lari, M. O., & Sahin, A. Z. Design, performance and economic analysis of a nanofluid-based photovoltaic/thermal system for residential applications. Energy Conversion and Management 2017, 149, 467-484.