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TiO_2-SiO_2 nanofluid characterization: Towards efficient with water/ethylene glycol mixture for solar application

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Abstract. Nowadays renewable energy has been used widely as strong contenders to improve the plight of two billion people, mostly in rural areas, without access to modern forms of energy. In this study, the effect of using water/ethylene glycol-based TiO_2-SiO_2 nanofluid on the characteristic of the solar radiation test rig has been experimentally used to investigate the characteristic of TiO_2-SiO_2 nanofluid suspended in water/ethylene glycol for solar applications. The TiO_2-SiO_2 nanofluids were prepared at a volume concentration of 0.3, 0.5 and 0.7% and dispersed in a base fluid of water/ethylene glycol 60:40 and 70:30 TiO_2-SiO_2 with the one-step method. KD2 Pro measures thermal conductivity set equipment and viscosity by LVDV III Ultra Rheometer. Thermal conductivity results show that the increase with different temperatures but the temperature of viscosity decreases. For solar radiation test rig that the highest point indicates the end of the charging process and the beginning of the discharging process, the maximum concentrations of 0.7% are observed to consistently provide higher temperature output as compared to the other three concentrations of nanofluids based on solar radiation 300, 500 and 700 W/m^2. Therefore, it can be concluded that the higher concentrations give ample time to the test tube to transfer the heat and thus increased its temperature during the charging process.

1. Introduction
Renewable energy sources play a crucial role in the effort of solving environmental problems efficiently and effectively for energy security and sustainability. Renewable energies are supplied (such as from biofuels, solar heat, photovoltaics, wind, hydro, wave, tidal. Geothermal, and ocean-thermal). Future development of renewable energy will enable a further reduction of environmental impacts. Renewable energy sources that meet domestic energy requirements provide energy services with zero emissions of both air pollutants and greenhouse gases [1]. Nowadays, it is about two billion peoples, mostly in rural areas depend on renewable energy sources without utilizing any modern forms of energy [2]. A further benefit of implementing renewable energy technologies in rural areas are provided job opportunities and at the same time, decrease the migration towards urban areas [3]. It

shows that renewable energy sources are not only important element in energy sustainability, but also contributes in improving the life of several communities as well.

In recent years, solar energy has become the most important source of energy. The usage of fossil fuels might be reduced in the future due to perceiving a shortage of fossil fuels and for the sake of the environment. Solar energy has become an alternative source of energy to overcome those barriers. Mostly solar energy applications are cost-effective and require only a few kilowatts of power for individual small systems [4, 5]. Utilization of solar energy should be applied in a wide range area since it contributes to energy stability improvement, increase energy sustainability, and increase system efficiency [6-9]. There are many studies conducted in solar, as reported in many kinds of literature [10-12].

Nanofluid is the common fluid which has been suspended with ultra-fine solid particles [13-16]. Commonly used fluids such as water, ethylene glycol, and heat transfer oil have contributed significant benefits to many industrial processes such as power generation, heating or cooling process, chemical processes, and microelectronics. However, the thermal conductivity of these fluids is relatively low and unable to reach high heat exchange rates in thermal engineering devices. In order to overcome this particular obstacle, various investigation of using nanofluid to improve the thermal conductivity of those fluids was carried out. Recently, the effects of nanofluids have been investigated by researchers on the enhancement of heat transfer in thermal engineering devices for experimentally and theoretically. Variety preparation methods, characteristics, and different models used for the calculation of thermo-physical properties of nanofluids has been applied by the researchers [17-24]. The effects of nanofluids on flow and heat transfer in natural and forced convection in different systems also have been summarized in some researches [25-29]. Special properties of nanofluids has given benefits in various applications.

Hybrid nanofluid is the new generation of nanofluid which composed of two variant types of dispersed nanoparticles in a base fluid. Investigation of various applications by using hybrid nanofluids has increased recently [10, 30-32]. Hybridization of nanofluids can increase the thermal conductivity of nanofluids. However, proper hybridization process is needed to get the best performance of hybrid nanofluid in heat transfer [30]. Hybrid nanofluid has served not only better performance in term of thermal conductivity than single-particle nanofluids but also provide high impacts of nanofluid utilization in present technologies [33-35].

Therefore, the objective of this study is to investigate the characteristic of TiO_2-SiO_2 nanofluid suspended in water/ethylene glycol 60:40 and 70:30 TiO_2-SiO_2 with one-step method for solar applications. This study will help researchers to get an idea about the effect of TiO_2-SiO_2 nanofluid based on thermophysical properties to apply to the whole system of solar used.

2. Materials and methods

2.1. Thermo-physical properties measurement

Thermal conductivity of the samples was measured using KD2 Pro thermal property analyzer of Decagon Devices, Inc., USA. The data were collected for a temperature range of 30 to 70 °C after two hours of the sonication process. Various investigators used KD2 pro thermal property analyzer in their measurements of thermal conductivity [36-41]. This instrument applied the transient hot-wire method. The present measurement method allowed the thermal conductivity measurement of nanofluids with minimum free convection effects. The experiment was performed five times for each sample and condition, and data point reported in this study represents an average of five measurements with an estimated error of ±1.2%. The set up for the thermal conductivity measurement is shown in figure 1 consists of a KD2 Pro thermal property analyser, water bath, a single needle sensor and a sample of hybrid nanofluids.

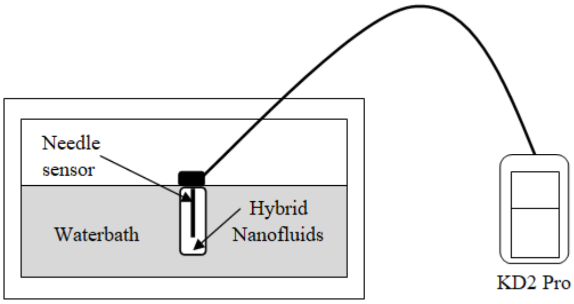


Figure 1. Apparatus and Instrument used in thermal conductivity measurement.

The viscosity of the nanofluids was measured using Brookfield LVDV-III Ultra Rheometer. Several investigators were used the same approach in their work for measurement of viscosity [42-44]. The viscosity was measured in temperatures between 30 °C and 70 °C, and the values were recorded at steady-state conditions, and 30 minutes was allowed to stabilize the temperature. The set up for the viscosity measurement is shown in figure 2.

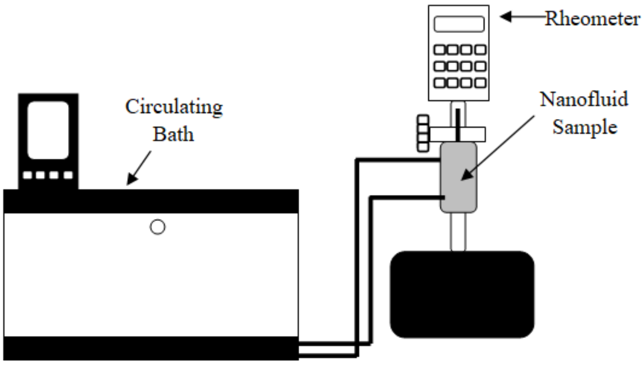


Figure 2. LVDV III Ultra Rheometer used in viscosity measurement.

2.2. *The set up for experiments*

Figure 3 shows the experimental setup with the solar simulator. Experiments were conducted for nanofluid concentrations ranging from 0.3, 0.5 and 0.7%. The parameters and properties involved in the experiment are given in table 1.

For each concentration, the data in the test tube is collected. The measurement of heat rates on solar simulators was taken using a pyranometer. Each preparation is exposed to short wavelength radiation under the solar simulator with 300, 500 and 700 W/m^2 for 30 minutes, of which 15 minutes is the heating period and the next 15 minutes for a cooling period.

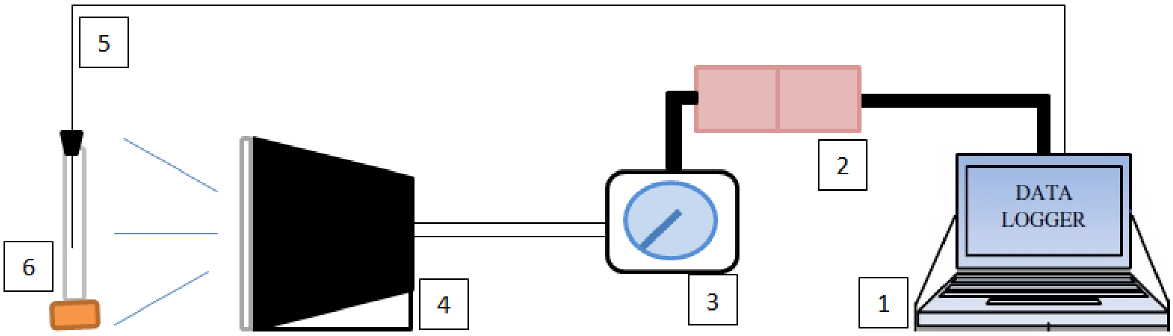


Figure 3. The solar radiation test rig.

Table 1. Detail description of the solar radiation test rig.

Description	Specification	Number
Data logger	ADAMView Advantech Data Acquisition	1
SSO	Switch Socket Outlet (Data Logger & Spotlight Dimmer)	2
Dimmer	Setting up with pyranometer (300, 500 & 700 W/m^2)	3
Spotlight	Halogen 500 W (1 Piece)	4
Thermocouple	K-type	5
Test Tube	100 ml	6

3. Results and discussion

3.1. Viscosity

Figure 4 shows the data analysis for the viscosity measurement under different temperatures for the various concentration of nanofluid. For instrument calibration, viscosity data for ethylene glycol was compared to viscosity in ASHRAE [45] and water/ethylene glycol. The viscosity using water/ethylene glycol was found to be higher for a temperature range of 30–70 °C.

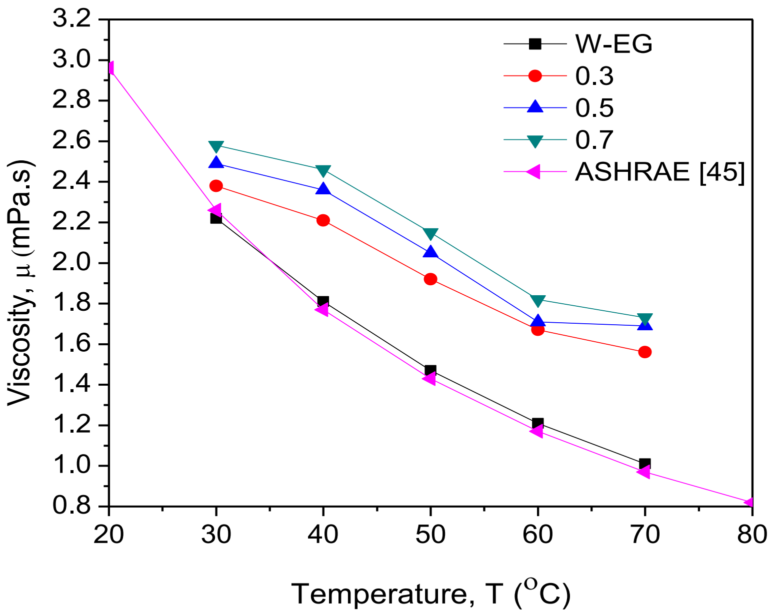


Figure 4. The viscosity of nanofluids with different temperatures.

Viscosity is essential in determining the properties of nanofluids. The viscosity of TiO_2-SiO_2 nanofluid is higher than the base liquid and increases according to the concentration of the liquid. For high volume concentration, it is clearly showing that the increase of viscosity concerning volume concentration and base fluid.

3.2. Thermal conductivity

Figure 5 shows the graph for the thermal conductivity measurement under different temperatures for the various concentration of nanofluid. At the stage of instrument calibration, measured thermal conductivity data for ethylene glycol was compared to thermal conductivity in ASHRAE [45] and water/ethylene glycol. The thermal conductivity using ethylene glycol was found to be higher for a temperature range of 30–70 °C.

The thermal conductivity of TiO_2-SiO_2 nanofluid was a maximum increase higher than the base fluid. The observation of this trend seems to be related to the Brownian movement. At high temperatures, particle collisions occur at higher rates, thereby bringing more kinetic energy.

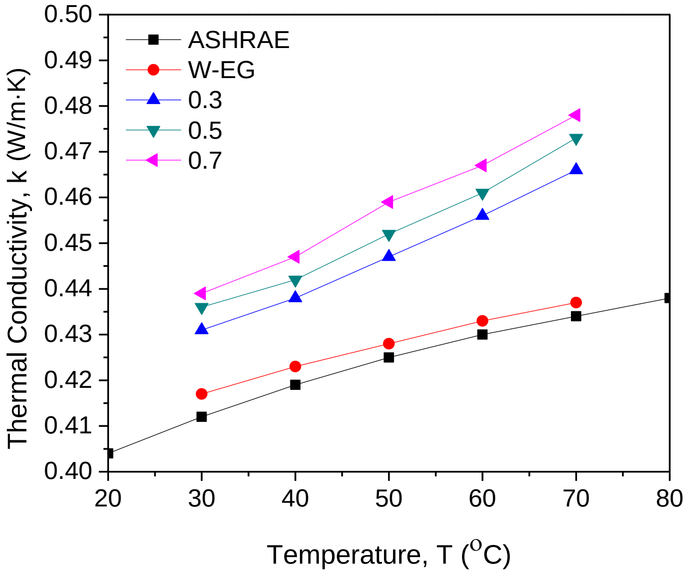
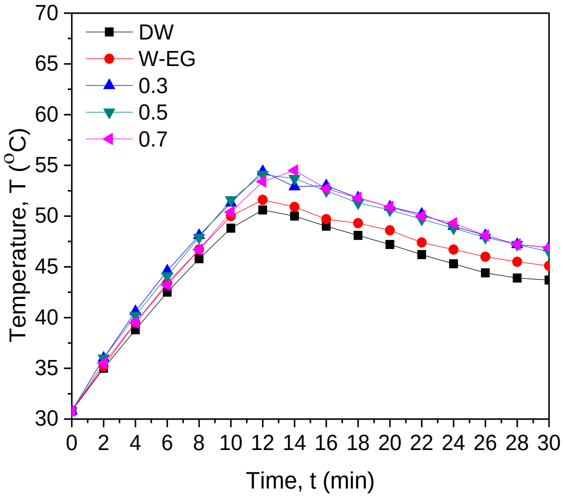


Figure 5. The thermal conductivity of nanofluids at different temperatures and volume concentrations.

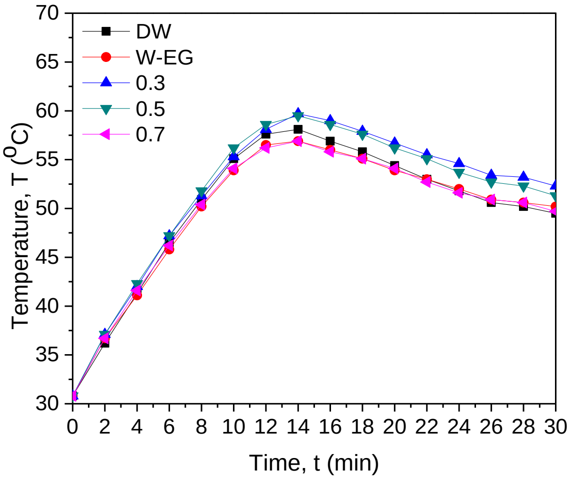
3.3. The Effect of TiO_2-SiO_2 nanofluid with water/ ethylene glycol based for absorber solar

The collected data obtained from the data logger, all data related to systems and collected by the k-type thermocouple. The absorber was appraised using the following essential indices, and the states of charge and discharge vary by time in a minute. In our case, to accurately assess the system, the findings were collected during the selected time, which is 15 minutes charging and 15 minutes discharging under different concentrations of TiO_2-SiO_2 nanofluids. All these results based on solar radiation 300, 500, and 700 W/m^2 as shown in figure 6.

For solar radiation of 300 W/m^2 and volume concentration of nanofluids 0.3, 0.5 and 0.7%, the maximum temperature achieved within 15 minutes of charging process is 53.0 °C, 52.5 °C and 52.7 °C respectively. Meanwhile, for solar radiation of 500 W/m^2, the temperature increases until the maximum value within the 15 minutes. However, for solar radiation 700 W/m^2, the volume concentration of nanofluids 0.3, 0.5, and 0.7%, the maximum temperature achieved 66.9, 65.3 and 67.2 °C, respectively. So, the result shows increasing rapidly for solar radiation 700 W/m^2 at the beginning of 15 minutes charging.



(a)



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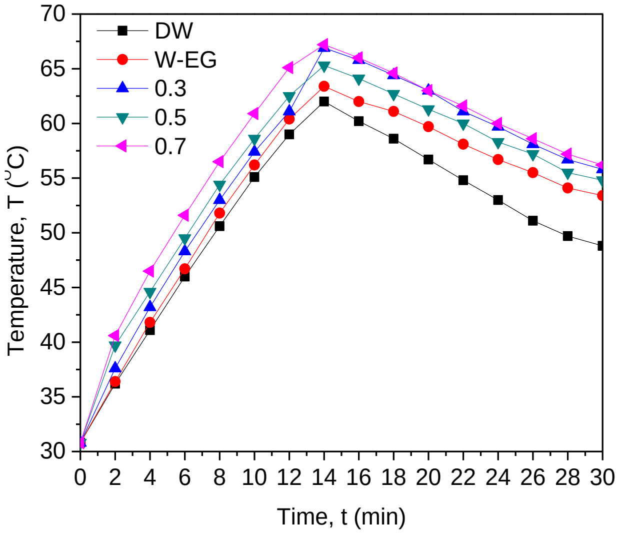

(c)

Figure 6. Temperature output of the absorber based on base fluid and nanofluids. Solar radiation (a) 300 W/m^2, (b) 500 W/m^2, (c) 700 W/m^2.

4. Conclusion

The present study aims to investigate the characteristic of TiO_2-SiO_2 nanofluid suspended in water/ ethylene glycol for solar applications. This study was attentive to the experimental of water/ethylene glycol in mixture ratios of 60:40 based 70:30 TiO_2-SiO_2 nanofluid for a wide range of temperatures from 30 to 70 °C and 300, 500 and 700 W/m^2 for solar radiation. Based on the obtained results, key findings of this investigation can be summarized as follows:

i. The viscosity of water/ethylene glycol-based TiO_2-SiO_2 nanofluid at 30 °C, and 0.3% of volume concentration was 2.72 mPa.s compared to base liquid which was 2.38 mPa.s and increases according to the concentration of the liquid.

ii. The thermal conductivity, *k* of water/ethylene glycol-based TiO_2-SiO_2 nanofluid at 0.3% of volume concentration was 0.431 W/m·K compared to the base liquid which was 0.417 W/m·K and increases according to the temperature difference. This trend seems to be related to the Brownian movement, which is bringing more kinetic energy.

iii. The higher concentrations give ample time to the test tube to transfer the heat and thus increased its temperature during the charging process under the solar radiation test rig. For volume concentration of nanofluids 0.3% and 300 W/m^2 of solar radiation, the maximum temperature achieved was 53.0 °C, and for solar radiation of 700 W/m^2, the maximum temperature achieved was 66.9 °C.

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