



Performance of heat transfer fluids with nanographene in a pilot solar collector

F.E.B. Bioucas*, S.I.C. Vieira, M.J.V. Lourenço, F.J.V. Santos, C.A. Nieto de Castro

Centro de Química Estrutural, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal

ARTICLE INFO

Keywords:

Nanofluids
Thermal solar collector
Nanographene
Efficiency

ABSTRACT

A pilot scaled solar collector was used to compare different heat transfer fluids, with a radiation source of a 1000 W halogen lamp, real time acquisition with a multiplexer and a Pt100 temperature control. The heat transfer fluid studied was a mixture of water and ethylene glycol 30% (w/w) with three different concentrations of nanographene (0.05, 0.08, 0.10 wt.%). The concentration that showed better results was used in a real test situation, without addition of dispersive agents. For both situations we report a higher efficiency of the collector, without visible clogging problems, due to the low nanomaterial concentration used.

1. Introduction

Although the energy source of solar energy is virtually inexhaustible, it is rarely constant since its availability is affected by the time of day and location, but also by weather and climate conditions. Consequently, it creates reliability problems and places this renewable technology at a disadvantage. However, solar collectors have great potential to provide affordable renewable energy since they are very versatile and can adapt to low temperature applications (domestic/commercial for water and space heating) and to high-temperature applications (district heating systems and solar thermal plants for process heat). The solar collectors that exist can be differentiated by the type of solar collector used (unglazed water collectors, evacuated tube collectors – hot pipes, flat plate collectors, glazed and unglazed air collectors, concentrating collectors) and the type of system operation (pumped solar thermal systems, thermosiphon systems) (Mauthner et al., 2016).

Solar equipment is an investment that must withstand some decades of operation and must maintain its operating performance so this long-term commitment should be robust in all its components and be able to withstand the thermal stresses it is subjected to. The life-cycle of the system, its efficiency and its cost will depend on the materials used in the construction and the normal operation of the solar collector. Research efforts are being made in order to overcome the problems presented by temperature variations and heat demand. These are particular to cold regions, where the demand in autumn and winter is substantial. Current systems of solar thermal energy have proven to be feasible and competitive in these climates, bringing more attention in increasing the technical expertise in materials that can lead to better efficiencies without diminishing the commercial interest with

expensive solutions (Rehman et al., 2017).

There is no one-size-fits-all solution, but there are some basic principles that can lead to higher energy efficiency. This can be done by optimizing thermal masses in a heat transfer fluid (HTF). The HTF carries heat through solar collectors and a heat exchanger to storage tanks. In a cold climate, solar water heating systems require fluids with low freezing points and since water, the most nontoxic and inexpensive HTF has a high freezing point and can present corrosiveness if the pH is not maintained at a neutral level, water-glycol mixtures are more suitable. Lately, other HTF are gaining more attention, depending on the operating temperatures of collectors. In low temperature applications there are the water-based nanofluids and for high temperature applications, nanofluid compositions based on hydrocarbon oils, ionic liquids and nanosalts are the most practical choice. Nanofluids possess advantages as dispersions of milli, micro or nano sized particles. They improve heat transfer capabilities and the stability of the suspension (Lourenço et al., 2014). A correct selection and preparation of a nanofluid as a HTF can result in reduced particle clogging of tubes. The experimental data for thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients of nanofluids compared with the base fluid demonstrated potential in engineering fields (Murshed and Nieto de Castro, 2014).

Verma and Tiwari (2015) reviewed the potential to enhance the functioning of various thermal systems of nanofluids. The review suggested that the selection of working fluid is of great importance in the design of the solar systems but the performance of nanofluids directly influences the overall efficiency of the system. Experimental and numerical studies established that thermal conductivity linearly increases with increase in volume percentage of nanoparticles in the base fluid;

* Corresponding author.

E-mail address: febioucas@fc.ul.pt (F.E.B. Bioucas).

<https://doi.org/10.1016/j.solener.2018.05.040>

Received 10 November 2017; Received in revised form 7 May 2018; Accepted 10 May 2018
0038-092X/ © 2018 Elsevier Ltd. All rights reserved.

Nomenclature		wt. %	mass fraction (%)
A	surface area of the absorber (m^2)		
C_p	specific heat capacity ($J \cdot g^{-1} \cdot K^{-1}$)		
DW	deionized water		
EG	ethylene glycol		
HTF	heat transfer fluid		
I	intensity of the radiation source ($W \cdot m^{-2}$)		
\dot{m}	mass flow ($g \cdot s^{-1}$)		
PVP	Polyvinylpyrrolidone		
STD	standard deviation		
T	temperature ($^{\circ}C$)		
TEM	transmission electron microscopy		
IEP	isoelectric point (zero zeta potential)		
		<i>Greek symbols</i>	
		ρ	density ($g \cdot cm^{-3}$)
		ϕ	volume fraction (%)
		η	efficiency of the solar collector (%)
		<i>Subscripts</i>	
		bf	base fluid
		nf	nanofluid
		np	nanoparticle

there is a lack of clarity in the behaviour of heat capacity, with experimental observations showing vary distinct responses with increasing volume fraction; viscosity of most of the nanofluids increases with solid volume concentration and depends on size, shape and type of the particle, type of base fluid, variation in temperature, particle to particle interaction, and agglomeration rate; and in general results show an enhancement in heat transfer efficiency of solar collectors. The limitations suggested are the instability of nanofluids, agglomeration or aggregation problems, increased pumping power, and erosion/corrosion of the heat transfer equipments. Therefore, it is a requisite for its success to follow certain methodologies for their preparation and stability in order to obtain the best nanofluid, custom-made to its intended use (Lourenço et al., 2014). The simpler nanofluids are bi-phasic systems with a solid phase dispersed in a liquid phase, forming dispersions.

In the recent years after Verma and Tiwari (2015), several studies deserve reference, which have used graphene based nanoparticles in water, which contributed in this field. Vakili et al. (2016a, 2016b) studied graphene nanoplatelets nanofluids in volumetric solar collector for domestic hot water systems, with low wt.% concentrations of the nanomaterial and found significant increase in the efficiency of the solar collector (up to 23.2% increase)¹. The stability of the nanofluid was tested by Vakili et al. (2016a). In addition the photothermal properties of graphene nanoplatelets nanofluids were also studied for the increase of solar energy absorption band Vakili et al. (2016b). Fan et al. (2017) also explored the plasmon resonance effect of graphene-embedded Sn@SiO₂@Ag nanofluid, which exhibits a strong absorption band in the range of 250–300 nm and 380–600 nm. The solar absorbance performance of graphene nanofluids was enhanced 2.9 times by adding 0.4 g/L Sn@SiO₂@Ag solutions. In addition the thermal conductivity of the nanofluid was also increased up to 16%. However no discussion of the application of the developed nanofluid in solar collectors was made. Šest et al. (2018) studied graphene nanoplatelets as an anticorrosion additive for solar absorber coatings, in order to design stable spectrally selective paint coatings for solar collectors and the findings are very encouraging, drastically improving corrosion resistance. This approach was also followed by Vieira (2016) using marine nanomaterials, the results being patented (Massonne et al., 2017). Finally Zhao et al. (2018) used the same type of nanofluids (graphene + water) but using a dispersive agent (PVP) and a vertical heat pipe, and compared with a conventional solar heat pipe, concluding for the superiority of using nanofluid to enhance the thermal performance of a solar gravity heat pipe, namely in steady-state operation.

A similar approach to that presented by Vakili et al. (2016a, 2016b) was followed in this work, but with different base fluid and in-house

two step preparation methods, without any dispersive agent (surfactant) added, with low sonication times to avoid the destruction of the nanomaterial particles/platelets. Detailed aspects of preparation can be found in Lourenço et al., 2014 and Nieto de Castro et al. (2017).

The efficiency of an alternative heat transfer fluid and its enhancement on the performance of a commercial solar collector kit was studied, both at laboratory and open-air environment. A common heat transfer fluid mixture (water + ethylene glycol) with nanographene different concentrations of the nanomaterial was sonicated. Our aim was to identify the nanofluid that showed higher efficiency but that wouldn't exert too much pressure in the solar collector loop due to pump failure caused by a higher viscosity forcing a system revamping. The mixture of water and ethylene glycol was chosen instead of water because the solar collector must endure all types of weather, and the heat transfer fluid has to be able maintain its liquid state at temperatures below 0 °C (Roriz et al., 2010). Nanographene was chosen since it has unique properties such as anomalous high thermal conductivity, although the reported data are rather scattered, with experimental values varying between 2000 $W \cdot m^{-1} \cdot K^{-1}$ and 600 $W \cdot m^{-1} \cdot K^{-1}$ and theoretical values varying in an even larger range, between 20,000 $W \cdot m^{-1} \cdot K^{-1}$ and 25 $W \cdot m^{-1} \cdot K^{-1}$ (Khanafer and Vafai, 2017; Wang et al., 2016). Thus the base fluid employed was water and ethylene glycol (70:30 wt.%) with three concentrations of nanographene (0.05, 0.08, 0.10 wt.%).

2. Experimental part

2.1. Solar collector

The solar collector was bought from PHYWE Company (Model 06753.00), but several modifications were made. In Fig. 1 the schematic of our solar collector is presented and in Table 1 the different parameters of the pilot unit are shown. In this work, we measured the temperature at four different points: cold current entering the collector (A), hot outlet currently leaving the collector (B), the temperature of the water bath (C) and the ambient temperature. A gear pump, a magnetic flow meter to measure the flow velocity, and a flow regulator valve to adjust the flow were used.

To measure temperature, five platinum resistance thermometers Pt100 with four wire connections were used, previously calibrated with an accuracy of 0.01 °C. The Pt100 and the pyranometer for the measurement of the intensity of the solar radiation were connected to an Agilent 34972A multiplexer with an acquisition time interval of 10 s. For the flow measurement, a magnetic flow meter (DIGIMESA, Model 31430-HD) was used, previously calibrated at ambient temperature with a stopwatch-and-weighing technique, coupled with a frequency meter (Ealing, Counter-Timer-Frequency Meter), to convert to flow. Measurements were done at 3 min intervals. All the Pt100 were isolated from the radiation source and the tubes of the unit and the water bath

¹ These authors must have a mistake in the weight fractions reported, sometimes in % and others in weight fraction. A factor of 100 makes conclusions very different. See discussion.

Download English Version:

<https://daneshyari.com/en/article/11011423>

Download Persian Version:

<https://daneshyari.com/article/11011423>

[Daneshyari.com](https://daneshyari.com)