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# Experimental investigation of graphene nanoplatelets nanofluid-based volumetric solar collector for domestic hot water systems

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**Abstract**

Today, with growth of population and increasing dependence of industry and technology on fossil energy, all communities and countries will face the challenge of energy in the future. Among all types of renewable energies, solar energy is a proper alternative to fossil fuels. For it is available in most parts of the world. In this study, the experimental investigation of volumetric solar collector's performance which is applied in domestic hot water has been shown for the first time, by making a laboratory sample of a volumetric collector, using innovative application of graphene nanoplatelets/deionized water with weight fractions of 0.0005, 0.001 and 0.005. The experiments were carried based on EN 12975-2 at different inlet temperatures and three mass flow rate of 0.0075, 0.015 and 0.225 kg/s. The results showed that the collector efficiency increases by the nanofluid weight fraction increase. According to the results, the maximum collector efficiency is obtained at 0.015 kg flow rate for both the base fluid and nanofluids. The zero-loss efficiencies using nanofluids with weight fractions of 0.0005, 0.001 and 0.005 were 83.5%, 89.7% and 93.2%, respectively; whereas the zero-loss efficiency was 70% using the base fluid.


*Keywords:* Volumetric solar collector; Graphene nanoplatelets nanofluid; Direct absorption; Efficiency

## 1. Introduction

Nowadays, energy is known as a key factor in modern life which provides foundation to economic growth. The issues like: rising expenses, depletion, security and environmental concerns, cause the renewable energy plays an important role in the future of the energy market (Organization for Economic Co-Operation and Development, 2014).

Investigation of different sorts of solar energy as an enormous and sustainable source of energy indicates the importance of the conversion and usage of the photothermal (Duffie and Beckman, 2013), due to not only thermal system, but also electricity (Lu et al., 2007) and chemical technology (Kamat, 2007).

In solar thermal systems, the properties of the working fluids which transfer heat from the absorber to the heat exchanger are very important (Michael and Iniyan, 2015). In recent decades, increasing the thermal conductivity and improving the thermo physical properties of fluids

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**Nomenclature**

| | |
|---|---|
| $A$ | area ($m^2$) |
| $a_1$ | heat loss coefficient ($W\ m^{-2}\ K^{-1}$) |
| $a_2$ | temperature dependence of the heat loss coefficient ($W\ m^{-2}\ K^{-2}$) |
| $c_p$ | specific heat (J/kg K) |
| $G$ | incident solar flux ($W/m^2$) |
| $\dot{m}$ | mass flow rate (kg/s) |
| $\dot{Q}$ | rate of useful energy gained (W) |
| $R^2$ | correlation coefficient |
| $T$ | temperature (°C) |
| $T^*$ | reduced temperature difference (°C) |
| $U$ | uncertainly |

*Greek symbols*

| | |
|---|---|
| $\varphi$ | volume fraction (%) |
| $\eta$ | collector efficiency |
| $\rho$ | density ($g/cm^3$) |
| $\tau$ | time constant of solar collector (min) |

*Subscripts*

| | |
|---|---|
| amb | ambient |
| $f$ | fluid |
| $G$ | gross |
| in | inlet |
| m | average |
| $n$ | nanoparticle |
| nf | nanofluid |
| $o$ | zero-loss |
| out | outlet |
| $T$ | total |

such as water, oil and ethylene glycol used in energy systems, has been regarded by researchers (Colangelo et al., 2015, 2012). Using nanofluids instead of common working fluids has been known as one of the innovative methods to enhance the thermo physical properties of the working fluids (Kulkarni et al., 2009; Nnanna, 2007). Hence, regarding the appropriate properties, nanofluids can be used in solar storage systems (Lenert and Wang, 2012), heat exchangers (Colangelo et al., 2012), cooling systems (Milanese et al., 2014) and solar systems (Gorji and Ranjbar, 2015) for increasing the efficiency. Many studies have been done on the nanofluid properties and the effect of the metal and non-metal nanoparticles on thermal conductivity (Lomascolo et al., 2015).

Colangelo et al. (2016) have investigated experimentally the thermal conductivity, viscosity and stability properties of $Al_2O_3$-diathermic oil nanofluid for use in solar system. They found that nanofluids compared with conventional fluid have good potential for use in high temperature solar system. Also their experimental work showed that the use of surfactants can be effective in the stability of nanofluids.

Xuan and Li (2000) showed that the nanofluid has great potential in enhancing the heat transfer process. One reason is that the suspended ultra-fine particles increase the thermal conductivity of the nanofluid remarkably. The volume fraction, shape, dimensions and properties of the nanoparticles affect the thermal conductivity of nanofluids. Sundar et al. (2013) investigated the thermal conductivity of ethylene glycol and water mixture based low volume concentration $Al_2O_3$ and CuO nanofluid experimentally and showed that using $Al_2O_3$ and CuO with even low volume fractions caused heat transfer increase.

According to results of thermal conductivity measurements of alumina/water and copper oxide/water nanofluids, Mintsa et al. (2009) showed the predicted overall effect of an increase in the effective thermal conductivity with an increase in particle volume fraction and with a decrease in particle size.

Gu et al. (2013) investigated the effective thermal conductivity of three water based nanofluids (NFs) consisting of large aspect ratio fillers carbon nanotubes (CNTs), silver nanowires, copper nanowires were measured by transient hot wire method. The results showed that materials with higher thermal conductivity is not a decisive factor and not always effective to improve the thermal transport properties of nanofluids. In recent years, most investigations have been performed on the carbon nanostructures including carbon nanotubes, graphite, graphene oxide and graphene nanoplatelets (Mehrali et al., 2014).

Graphene, single layers of hybridized $SP_2$ carbon atoms arranged in a honeycomb lattice, as a multi role nanoparticle with special mechanical, electrical, conductivity properties attract scientists' attention these days (Novoselov et al., 2005). In a graphene sheet, one carbon atom connected to three carbon atoms, these three bonds located in one plate with equal angels (120). In this case carbon atoms form hexagon shaped network (Geng et al., 2015). Graphenes are two-dimension (2D) crystals, which exist in multi-layer shapes. The single layer graphene has the same thickness with a carbon atom layer. This new-born article with its unique properties causes scientists to examine it for more usage in future (Singh et al., 2011).

Therefore, due to the unique properties of graphene nanoparticles, in present work, for the first time, the performance of nanoparticles, as an absorber in direct absorption or volumetric collector at low temperatures, was investigated and also the optical properties nanoparticle was measured in domestic hot water systems.

Gupta et al. (2011) experimentally investigated the thermal conductivity of graphene nanofluid and showed that