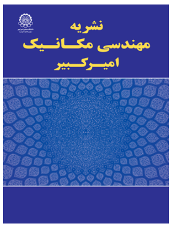

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Experimental Study of the Effect of Magnesium Oxide and Multi-Walled Carbon Nanotubes Hybrid Nanofluid on Increasing the Absorption Efficiency of Solar Radiation

R. Ghanbari, M. M. Heyhat*

Department of Mechanical Engineering, Tarbiat Modares University, Tehran, Iran

ABSTRACT: The solar radiation absorption efficiency is one of the challenges for engineers in solar energy systems. Using the hybrid nanofluids, which are obtained by dispersing two or more types of nanoparticles in the base fluid, can be effective in better absorption of solar energy. In this study, the effect of type, concentration, and mixing percentage of nanoparticles on optical properties and solar thermal utilization efficiency has been tested. First, magnesium oxide nanofluids and multi-walled carbon nanotubes with water-based fluid were fabricated by a two-step method in volumetric concentrations of 0/01%%Vol, 0.02% Vol, and 0.04%Vol, and then the optical properties of single and hybrid forms were measured by spectrophotometer and have been compared by existing relations. Then, to obtain the solar thermal utilization efficiency, a solar simulator has been used. The results show that increasing the concentration of nanofluid, improves the optical properties and solar radiation absorption efficiency. Magnesium oxide nanofluid, multi-walled carbon nanotubes, and hybrid nanofluid have the values of extinction coefficient about 38, 40, and 50 times higher than pure water, respectively. The hybrid nanofluid absorbs more than 90% of the sun's energy at the highest concentration (0.04% Vol) and at a penetration depth of 0.3 cm. Solar energy absorption increases by increasing the concentration, hybridizing the nanofluid, and increasing the penetration distance.

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1- Introduction

Nowadays, to reduce carbon dioxide emissions and protect the environment, the usage of renewable energy has been a priority in research. Researchers have offered direct and indirect ways to enhance solar energy efficiency. Due to the benefits of thermophysical and optical properties of nanofluids over the base fluid, they suggested the nanofluid as a suitable alternative to the base fluid in solar energy absorbing systems. The utilization of nanofluids as a direct adsorption environment (volumetric adsorbent) will have advantages and capabilities such as improving heat transfer, reducing the size of heat transfer systems, and improving efficiency. Then, other experts have studied nanofluids by dispersing two or more nanoparticles in the base fluid called hybrid nanofluids. They tested nanofluids that were cost-effective, had a wide absorption spectrum, and had significant heat transfer properties relative to the base fluid [1]. Menbari et al. [2] investigated the effect of hybrid nanofluids of alumina and CuO on the performance of direct adsorption parabolic collectors. They combined two different nanoparticles, one of them with high adsorption potential and the other one with high dispersion potential, in different base fluids. They found that collectors with hybrid nanofluids were more efficient than collectors using single nanofluid. Valizade et al. [3] analyzed the optical properties of CuO nanofluid, SiC, and their porous foam. In this study, the extinction coefficient was examined in the concentrations of 0.01% and 0.1%, while the porosity was 90 and 95%. Their results showed that the amount of extinction coefficient increased by 176% and 20%, respectively. Chen et al. [4] tested the optical properties of Multi-Walled Carbon Nanotube (MWCNT) in a solar system as a volumetric adsorbent. Based on their results, with increasing the concentration of nanofluid, an increase in the efficiency of the solar system was observed. The highest thermal efficiency (95%) occurred in nanofluids with a weight concentration of 0.002% in the first 10 minutes of the experiment. In addition, the transmittance of carbon nanotubes decreased with the darkening of the nanofluid and the extinction coefficient increased with decreasing the transmittance. Mohan et al. [5] evaluated the performance of a linear solar collector with a CuO hybrid nanofluid with a volume concentration of 0.2% and 0.25% TiO2. They observed that the optical and thermal properties of the hybrid nanofluid at low concentrations were also significantly superior to the base fluid. Also, the photothermal conversion rate in the hybrid nanofluids was increased with the increment of volume concentration. According to studies, we have witnessed the significant effect of hybrid nanofluids in the

*Corresponding author's email: mmheyhat@modares.ac.ir

enhancement of the optical properties and efficiency of solar systems in recent years. Choosing a nanofluid that can have significant radiative properties has always had challenges. In this study, we tested a hybrid nanofluid from MgO nanofluids and an MWCNT to introduce it as a suitable working fluid for solar systems.

2- Methodology

The current study investigates the hybrid nanofluid to analyze optical properties. The powder of MgO with a particle diameter of 20-30nm and stable nanofluid consisting of an MWCNT with a particle diameter of 20-30 nm were purchased. To provide the MgO nanofluid, in the initial stage of the process, to dissolve the Polyvinyl Alcohol (PVA) powder in distilled water. As soon as making PVA fluid has carried out, we added MgO nanoparticles with two steps method to achieve the highest concentration of the experiment. An ultrasonic homogenizer was applied to disperse the nanoparticles in the base fluid. Finally, combining 0.01, 0.02, and 0.04%Vol. of nanofluids in the ratio of 30:70, 50:50, and 70: 30 to make hybrid nanofluids were performed. The optical properties of nanofluids were measured by a spectrophotometer. In this study, due to the concentration of less than 0.6% of nanofluids, we used an extinction coefficient to measure the absorption of nanofluids, which is obtained according to Eq. (1) [3, 6]:

$$\text{Transmittance} = e^{-k_e(\lambda)L} \tag{1}$$

3- Results and Discussion

Fig. 1 presents two peaks of extinction coefficient in 0.04Vol% hybrid nanofluid, one of which is located in the ultraviolet region and the other in the visible region. According to this diagram, the extinction coefficient of hybrid nanofluid with 70% of MWCNT has a higher value in the ultraviolet region. Fig. 1 presents two peaks of extinction coefficient in 0.04Vol% hybrid nanofluid, one of which is located in the ultraviolet region and the other in the visible region. According to this diagram, MgO nanofluid had a higher absorption spectrum in the visible and infrared region, but carbon nanotube nanofluid had a higher absorption spectrum in the ultraviolet region. Also, in the highest concentration of this experiment, due to the darkening of the nanofluid, the extinction coefficient increased. The extinction coefficient of the hybrid nanofluid in 0.04Vol% had 42 and 50 times increment compared to the base fluid in the ultraviolet and visible region, respectively. The results of the extinction coefficient in this study (Figs. 1a, b) have a good agreement between the results of Suraj et al. [7] for MgO and the results of Chen et al. [4] for MWCNT. The difference between the results can be due to the quality of the test materials, the size of the used nanoparticles, and the model of the measurement devices.

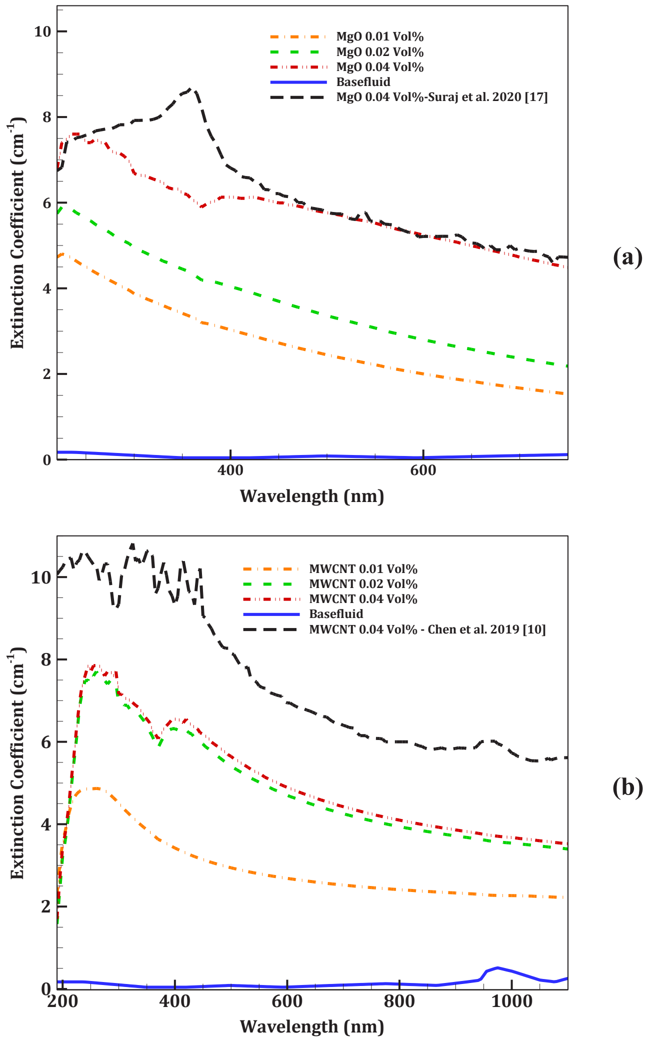

Fig. 1. extinction coefficient a) MgO in the current study with Suraj et al. b) MWCNT in the current study with Chen et al.

4- Conclusions

In this research, MgO and MWCNT were fabricated by a two-step method in volume concentrations of 0.01, 0.02, and 0.04% and hybrid ratios of 30:70, 50:50, and 30:70. Increasing the nanofluid concentration resulted in an increase in extinction coefficient of 58.5 for MgO, 60% for MWCNT, and 11% for hybrid nanofluid. In MgO, the extinction coefficient enhancement was 38-times, 40-times for MWCNT, and 50-times for hybrid nanofluids compared to the base fluid.

The solar weighted absorption fraction by hybrid nanofluid at the lowest test concentration (0.01% by volume) at a penetration depth of 0.9 cm, at 0.02% at a penetration depth of 0.5, and 0.04% in the penetration depth of 0.3 cm is more than 90% of solar energy. These results demonstrate the effect of penetration distance and concentration of nanofluid on increasing the amount of solar energy absorption by a nanofluid.

In computing the solar thermal efficiency, hybrid nanofluids improved the solar thermal efficiency due to the higher equilibrium temperature. So that this amount in single nanofluids was 85% and 87% for MgO and MWCNT at a volume concentration of 0.04%, respectively. But this value is estimated to be about 90% for hybrid nanofluids. The small discrepancy between these values and the solar weighted absorption fraction has caused a satisfactory result of this present study.

The hybrid nanofluids of MgO and MWCNT have a wide and high absorption spectrum in different areas. Therefore, hybrid nanofluid can be used as a working fluid for solar energy systems and witnessed the realization of energy conversion goals, including improving efficiency and optimization in solar systems.

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