ORIGINAL RESEARCH PAPER

The Study of Thermal Conductivity Silver/Water Nanofluid

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ABSTRACT
In present study, the thermal conductivity of silver/water nanofluid was investigated experimentally. Four different volume concentrations of nanofluids (2, 3, 5 and 10%) were prepared by dispersing silver nanoparticles in water. The properties of nanofluids were measured by varying the temperature from 20ºC to 100ºC and also, different sizes of nanoparticles dispersed in water (20-30, 50-60 and 100-110 nm). The obtained results demonstrate that the thermal conductivity of nanofluids is the function of volume concentration, nanoparticles size and temperature. In addition, the impact of nanoparticles on the viscosity of the fluid was studied at different concentrations.

Keywords: *Thermal conductivity; Silver/water nanofluid; Volume concentration*

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INTRODUCTION

Nanofluids have been a new research area for the past years as an approach to enhance the heat transfer rate in many applications. Many investigations through experimental works, mathematical modeling and simulation have been done to begin with the massive implementation of nanofluids in important modern equipment and systems like air conditioner, automotive cooling system, electronics, and medical equipment. Nanofluids are a potential fluid with superior properties to replace conventional fluids such as water, deionized water, refrigerant, coolant, lubricant, etc. The term of "nanofluids" has been introduced by Choi in 1995 at Argonne Research Laboratory as an advanced fluid that showed superior heat transfer properties with nanoparticle suspensions [1,2]. There are two methods to prepare nanofluids. Nanofluids prepared by single-step method are more stable than those by two-step method. However, the two-step method is applicable in the fabrication of almost all kinds of nanofluids. Single-step method is a procedure that combines the production of nanoparticles with the synthesis of nanofluids. Vapour Deposition is the most commonly used single-step method at present. Currently, two-step method is the most commonly used method for the preparation of nanofluids. Generally, two procedures are involved in this method. The first procedure is the synthesis of nanomaterial, which is usually in the form of dry powder. The second procedure is the dispersion of nanomaterial in the base liquid such as water, ethanol and ethylene glycol. During this procedure, some measures, for instance, addition of dispersant or sonication, are generally carried out to enhance the stability of the resulting nanofluids [3, 4]. The effectiveness of heat transfer enhancement is known to be dependent on the amount of dispersed particles, material type, particle shape, and so on. It is expected that nanofluid can be utilized in airplanes, cars, micro machines in MEMS, micro reactors among others. Before the introduction of nanofluid, it was expected that heat transfer could be enhanced by dispersing micron-sized particles. But the

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fluid with micron-sized particles caused problems due to sedimentation and clogging. Most of all, the fluid with micro sized particles was found to be not efficient enough. Since the concept of nanofluid has been first introduced by Eastman and Choi (1995), there have been many efforts to understand the mechanism of heat transfer enhancement together with experimental measurements of the thermal conductivity of nanofluids and the methods of utilization of nanofluids. However, there has been no established mechanism for the heat transfer enhancement. The reason may arise from the difficulty caused by the fact that the heat-transfer between the base fluid and particles occurs while the particles are in random Brownian motion. Also, depending on the flow condition and chemical nature of particles, dispersion state can be different. Xuan and Roetzel (2000) suggested a mechanism by assuming that nanofluid behaves similarly to common solid suspensions in liquid. Keblinski et al. (2002) argued that the heat transfer increases due to the combined effect of Brownian motion of nano-particles, formation of liquid-solid interface, large conductivity of the particle itself and clustering of nano-particles [3, 4, 5, 6].

Thermal conductivity signifies the inherent ability of heat transfer and it is very important property for all thermal applications involving fluids. Heat conduction depends upon thermal conductivity. Furthermore, Nusselt number, an important parameter in convective heat transfer is directly related to the thermal conductivity of fluids. So, comprehensive study of thermal conductivity of nanofluids is of paramount importance. Previous reports have described about the measurement methods of thermal conductivity of nanofluids. Furthermore, those also have given description on how the various parameters such as shape, size, volume fraction and temperature of nanofluids individually affects the thermal conductivity of nanofluids [7, 8, 9, 10].

In this work, four different volume concentrations of nanofluids (2, 3, 5 and 10%) were prepared by dispersing silver nanoparticles in water. The properties of nanofluids were measured at 20°C, 40°C, 60°C, 80°C and 100°C and also, different sizes of nanoparticles dispersed in water (20-30, 50-60 and 100-110 nm). In addition, the impact of nanoparticles on the viscosity of the fluid was studied at different concentrations.

MATERIAL AND METHODS

Powder of Silver nanoparticles was purchased from Sigma-Aldrich (Germany). The silver/water nanofluids with different volume concentrations were prepared by dispersing silver nanoparticles with sizes of 20-30 nm, 50-60 nm and 100-110 nm into distilled water. In the present study, four different volume concentrations of nanofluids (2, 3, 5 and 10%) were prepared by dispersing silver nanoparticles in water. Also, thermal conductivity was measured at 20°C, 40°C, 60°C, 80°C and 100°C. The thermal conductivity of nanofluid was measured by following apparatus using Fourier's law The apparatus was designed by Radman Sanat Company.

$$q=-kA\, \partial T/\partial r \qquad (1)$$

In the above equation, q is heat flow rate, $\partial T/\partial r$ is the temperature gradient in its one-dimensional form and k is the thermal conductivity of nanofluid. In addition, the viscosity of silver/water nanofluid was studied in concentrations of 2, 3, 5 and 10% by Brookfield DV II Viscometer.

RESULT AND DISCUSSION

The effect of nanoparticles concentration on thermal conductivity

Particle volume concentration is regarded as the most significant factor affecting the thermal conductivity of nanofluids. To study the effects of silver nanoparticles on the thermal conductivity, nanofluids were prepared in volume concentrations 2%, 3%, 5% and 10% and thermal conductivity was recorded at different concentrations. As shown in Fig. 1, the thermal conductivity of fluid enhances with adding silver nanoparticles. This is due to the thermal conductivity of nanoparticles is the higher of the base fluid. When the nanoparticles are added to the base fluid, thermal conductivity increases depending on the amount nanoparticles added.

The effect of temperature on thermal conductivity

Most of the studies have demonstrated about temperature dependency of nanofluids. However, there is considerable disagreement in the literature regarding the temperature dependence of their thermal conductivities. In this study, the thermal conductivity of nanofluid was evaluated in different concentrations at 20°C, 40°C, 60°C, 80°C and 100°C. As shown in Fig. 1, the thermal conductivity of nanofluid increases with increasing temperature. The reason of this matter is increasing nanoparticles motion and consequently increasing collisions of nanoparticles. Increasing collisions of nanoparticles with other particles increase the heat transfer of fluid and thus increase the thermal conductivity of nanofluid.

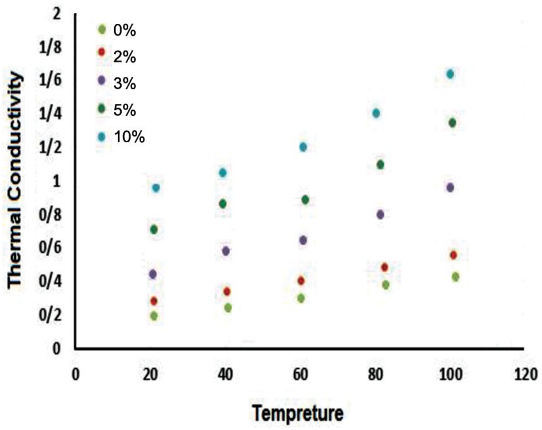

Fig. 1. The effect of nanoparticles concentration on thermal conductivity of silver/water nanofluid in different temperatures.

The effect of nanoparticles size on thermal conductivity

Particle size is another important parameter that affects thermal conductivity of nanofluids. In this work, it was used 3 types of nanoparticles with sizes from 20-30 nm, 50-60 nm and 100-110 nm to investigate the effects of nanoparticles size on the thermal conductivity. All samples were considered at 20°C. As is clear from the graph, the thermal conductivity of the fluid increases with increasing the particle size in similar concentration. The reason behind such behaviour is the increase in specific surface area with the decrease in size contributes to the enhancement in thermal conductivity. For nanofluid with particle size of 100-110 nm, thermal conductivity decreases with increasing concentrations of nanofluid in higher concentrations of 5%. This is due to the nanoparticles sticking to each other and agglomeration (Fig. 2). This phenomenon was confirmed by SEM and TEM (Fig. 3). Chopkar et al. was first to show that thermal conductivity bears a nonlinear relationship with the nanoparticle size [15]. Chon et al. and Hong et al. observed that thermal conductivity of nanofluids increases with decrease in particle size [16, 17]. Most recently, Kim et al. showed that the thermal conductivity of nanofluids increases linearly with decrease in particle size [18]. However, our result was confirmed by others experimental data.

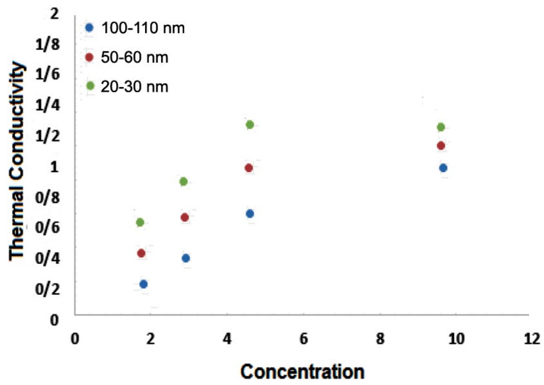

Fig. 2. The effect of nanoparticles size on thermal conductivity of silver/water nanofluid in different concentrations.

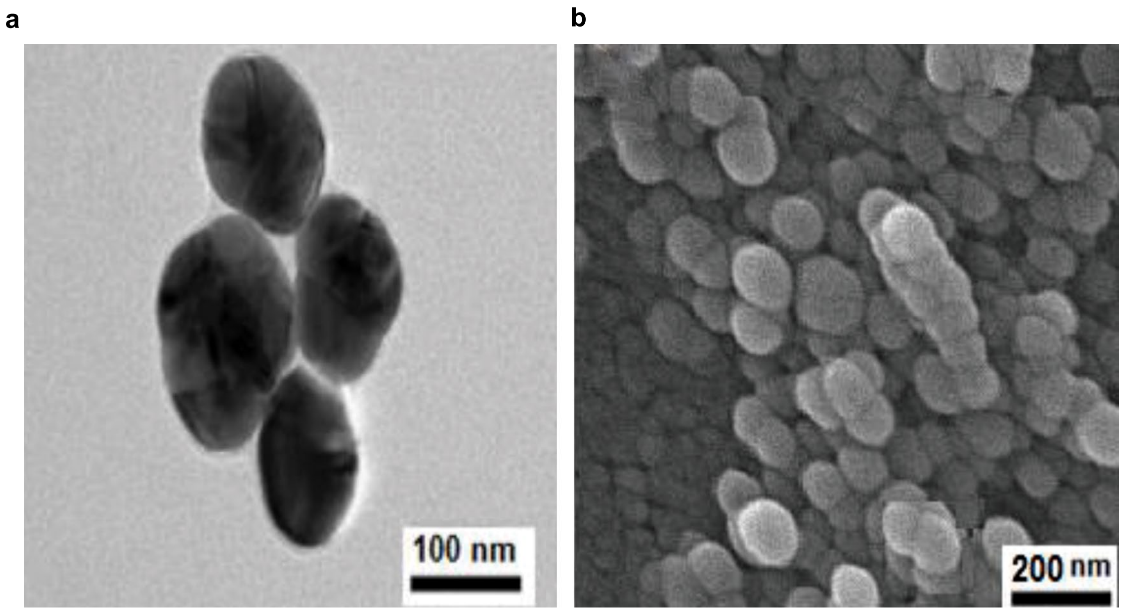

Fig. 3. (a) TEM, (b) SEM of silver/water nanofluid in concentration 10% for nanoparticles with size 100-110 nm.

The effect of nanoparticles concentration on viscosity

Very few investigations have been done till now on this topic. It has been found that viscosity has an impact on the thermal conductivity of these fluids. Fig. 4 shows the effect of nanoparticles concentration on the viscosity of base fluid. As is clear from the graph, fluid viscosity increases with increasing nanoparticles concentration in base fluid. This increase is due to the presence of solid particles in the fluid. The reason of this phenomenon is increasing nanoparticles motion and consequently increasing collisions of nanoparticles and finally a higher fluid viscosity.

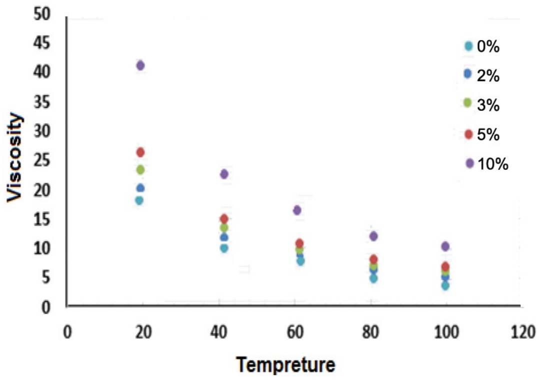

Fig. 4. The effect of nanoparticles concentration on viscosity of silver/water nanofluid in different temperatures.

CONCLUSION

In this work, the thermal conductivity and viscosity of silver/water nanofluids were studied at different concentrations, various sizes and several temperature conditions. Thermal conductivity and viscosity of nanofluids increases with increasing volume concentration of silver nanoparticles. Moreover, the thermal conductivity of silver/water nanofluid increases with enhancing temperature and its viscosity decreases with increasing temperature. In addition, thermal conductivity increases with enhanced particle size while for nanofluid with particle size of 100-110 nm, thermal conductivity decreases with increasing concentrations of nanofluid in higher concentrations of 5% due to the nanoparticles sticking to each other and agglomeration. It confirms by TEM and SEM analysis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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