Effect of surface tension on SiO2–methanol nanofluids.

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Abstract. Surface tension, the cohesive energy of an interface dominated the transportation behaviour of the liquids play an important role in the heat transfer performance. A new class of heat transfer fluid denoting “Nanofluids” with impressive thermo-physical properties, proved its promising potentiality in the heat transfer performance. However, very few numbers of studies observed for the effect of nanoparticles on the surface tension of liquids, also noted controversial results. In the present study, SiO2 nanoparticles dispersed in methanol solution to investigate the effect of surface tension with the change of concentration and their sizes. The most common Du–Noity ring method was used to measure the surface tension of methanol based nanofluids by an automatic surface tensiometer. The results denote that the surface tension of the nanofluids increases with increase in concentration. On the other hand, the results indicate that the surface tension decreases with the increase in temperatures. Besides, the surface tension of SiO2–methanol nanofluids enhances compared to pure methanol. All in all, the enhancement observed 1.7% to 8.9% of the variation of volume fractions (0.05 Vol % to 0.25 Vol %) and the temperature change of 25 °C to 50 °C.

1. Introduction:

Enhancing the heat transfer is one of the foremost apprehensions in the research community to save the energy of a thermal system due to it is anticipated that all the energy of the universe will spring up over 50% in the next 25 years. A colloidal mixture denoting “Nanofluids” is the suspension of nanoparticles (normally less than 100 nm) in the conventional fluids introduced by Choi et al. [1]. It has shown dramatic improvements of its thermophysical properties and used in various applications in the field of heat transfer [2]. Besides all other properties, surface tension of the fluids has significantly influenced the heat transfer performance of a thermal system. It is the amount of surface free energy per unit area of the liquid droplets [3]. Surface tension is the force which influences the surface wettability [4], bubble growth, and enhances the boiling heat transfer coefficient [5]. Moreover, the capillary action causes by surface tension of the working fluid transfer the liquid from the condenser to evaporator, which influences to increase the thermal performance of the heat pipes [6]. However, most of the experimental and theoretical studies investigated thermal conductivity, viscosity, density and specific heat of the nanofluids [7, 8]. Besides, some studies were executed to measure the surface tension of the nanofluids [9]. Therefore, it is imperative to examine the effect of nanoparticles on the surface tension of the conventional heat transfer fluids.

There is no significant change on surface tension observed while measuring the Al2O3–H2O nanofluids [10]. Zhu et al. [11] reported surface tension of Al2O3–H2O nanofluids decrease with the increase in concentration and temperatures. Moreover, they observed that smaller nanoparticles showed lower surface tension than a larger one. However, Tanvir et al. [12] found surface tension of the nanofluids enhances with the increase in both the concentration and particle sizes. Similarly, Majid...
Moosavi et al. [13] demonstrated the ratio of surface tension of ZnO/EG nanofluids increases with the increasing the volume fraction. Further, Murshed et al.[14] pointed that the surface tension of TiO2- DIW nanofluids reduced linearly with the change of temperature 25°C to 55°C at 0.1 Vol%. Furthermore, surface tension of Bi2Te3 nanoparticles in aqueous solution at first decreases, and, again rises with the increase in concentration observed by Saeid Vafaei et al. [15]. Therefore, the earlier studies demonstrated that the effect of surface tension of the nanofluids governed by the concentration, temperatures and nanoparticle sizes.

Besides water, methanol is the most widely used heat transfer fluids used in the different applications [16, 17]. Moreover, Kim et.al[18] observed mass transfer enhancement in Al2O3-methanol nanofluids. Further, methanol based nanofluids showed their performance in the absorption of carbon dioxide (CO2) gas [19, 20], HVAC system [21], heat pipes and air-conditioning system [22]. Therefore, methanol based nanofluids is potential to enhance the heat transfer rate of heat exchangers and save on energy. Additionally, some literatures were found about methanol based nanoluids. Nevertheless, most of them were discussed only the thermal conductivity and rheological properties [23, 24]. In the present experimental study, the authors investigate the effect of SiO2–methanol nanofluids on surface tension for the change of volume fractions (0.05 Vol % to 0.25 Vol%) along with the variation of temperatures (25 °C to 50 °C).

2. Experimental process

2.1 Materials and sample preparation

SiO2 (5–15nm) nanoparticles purchased from Sigma Aldrich, Malaysia. The base fluid, methanol (CH3OH) with 99.9% purity was purchased from R&M Chemical, Malaysia. In this study, the two-step method applied to prepare the nanofluids with the volume fraction of 0.05 Vol % to 0.25 Vol %. At first, the required mass of the nanoparticle calculated by a digital weight gauge and dispersed in the measured amount of methanol (CH3OH) for the preparation of an individual volume fraction of nanofluids. Then, the solution vibrated in an incubator type mechanical shaker for 1 h at 150 RPM to homogenize the mixture. After that, an ultrasonic homogenize used to distribute the nanoparticles uniformly and evenly in the solution by producing high amplitudes and as well breaking the particle clusters. The sonication process continued for 2 h at the frequency of 10 kHz (50% amplitude) in a series of 2–second long pulses in 2 seconds apart along with a cooling bath to maintain a constant temperature (10°C) within the mixture.

2.2 Surface tension measurement

An automatic surface tensiometer (DCAT 11EC, Data Physics Instruments GmbH, and Germany) was used to measure the surface tension of SiO2–methanol nanofluids. The measuring range of the instrument is 1 to 1000 mN/m; ± 0.001 mN/m. Platinum-iridium RG11 Du–Noüy rings (Part no2000321), 70 mm diameter sample vessels, and electric hand dryer were used to conduct the experiments. The experimental results were evaluated by SCAT 31 software. And, the traditional Du–Noüy ring method (DIN 53915 and ASTM-971) applied for this experiment. In this method, the ring emerged and dipped from or into the sample vessels by an inward pushed or outward pulled lamella. The surface tension was measured by the changes of the ring weight during pushing and pulling. Figure 1 shows the surface tension measurement by pulling and pushing of the ring during the interval of time. Three readings took for a particular volume fraction, and the average value was considered for the final calculation. All the measurements were executed at an atmospheric pressure.
3. Result and discussion

3.1 Effect of volume fractions on the surface tension of the nanofluids

The effect of surface tension of SiO$_2$-methanol nanofluids is shown in Figure 2 with the variation of volume fractions (0.05 Vol % to 0.25 Vol %). The diagram clearly represents that the surface tension of the nanofluids increases with the increase in volume fractions. For instance, the value of the surface tension changes from 22.84 mN/m to 23.17 mN/m for the variation of volume fractions (0.05 Vol % to 0.25 Vol % at 25 °C. Moreover, the results represent the similar trends for other’s temperatures. The results of this study are analogous with the experimental study of Tanvir et al. [14]. The results might be happened, as the volume fraction increases, more nanoparticles gathered into the solution. So, the nanoparticles are trying to get close with the surface molecules. As a result, a strong, cohesive force was exerted between the nanoparticles and liquid molecules, and hence, the surface tension of the nanofluids increases with the increase in volume fractions [14]. Moreover, the mean distance between the liquid molecules and the nanoparticles reduces with the increase in volume fractions. Thus, the surface to volume ratio increases, and consequently, increases the surface energy, and accordingly, the surface tension of the nanofluids increases.

Figure 2. Surface tension of SiO$_2$–methanol nanofluids as a function of volume fractions.

3.2 Effect of temperature on the surface tension

Figure 1. Surface tension measurements of nanofluids as a function of time.
Apart from the change of volume fractions, the variation of temperatures from 25 °C to 50 °C influences the outcomes of the surface tension of the nanofluids. In the figure 3, the results of the surface tension of SiO$_2$–methanol nanofluids are exhibits with respect to the change of temperatures. The results clearly indicate that the surface tension of the nanofluids decreases linearly with the increase in temperatures. For example, the plot demonstrates that the surface tension of the SiO$_2$methanol nanofluids dropped from 22.84 mN/m to 21.91 mN/m for the temperature change from 25 °C to 50 °C at 0.05 Vol %. The similar trends were observed in the experimental study of Murshed et.al [16]. As the temperature increases, the kinetic energy increases, and hence, rapidly accelerated the molecules of the nanofluids. As a result, the molecules are expanded from each other, and thus, weakening the strength of the intermolecular forces, which reduces the surface tension. Moreover, the density of the liquid molecules decreases with the increase in temperatures. Therefore, the shearing forces of the liquid layers reduce and resulting a lower value of the surface tension. Further, nanoparticles increases the Brownian motion in the liquid molecules, which lessen the cohesive energy and the resultant reduces the surface tension of the nanofluids.

Figure 3. Surface tension of nanofluids as a function of temperatures.

3.3 Enhancement of surface tension of the nanofluids

Though the surface tension of SiO$_2$–methanol nanofluids increases with the increase in concentration and decreases with an increase in temperature, the surface tension of the nanofluids enhances in all cases in comparison with the base fluid (methanol). The figure 4 shows that the values of the surface tension of pure methanol are measured as a function of temperature. Besides, the figure 5 exhibits, the enhancement of the surface tension of the nanofluids as function of temperature and volume fractions. The highest enhancement was observed about 4.27% to 8.92% for 0.25 Vol % at the temperature variation of 25°C to 50 °C. Moreover, the similar results are shown in other’s volume fractions. Overall, the lowest improvements exhibit 1.72% for 0.05 Vol % at 30 °C. The surface tension of nanofluids will increase or decrease depends on the forces of solid-liquid are attractive or repulsive. As the nanoparticles added to the liquid, the molecules interact with each other. As a result, the forces of nanoparticles with its adjacent nanoparticles along with the liquid molecules are exerted in the liquid surfaces. Hence, an attractive Van der Waals force is employed, which resulting the enhancement of surface tension. The findings are similar with the outcomes of Moosavi et al. [15]
4. Conclusion

The results of the experimental study inferred that surface tension of nanofluids changes with the change of concentration and temperatures. The following observations are the outcomes of this study.

a) The surface tension of the SiO₂ methanol nanofluids increases with the increase in concentrations due to nanoparticles increased the surface energy by increasing the surface to the volume ratio in the nanofluids.

b) Surface tension of nanofluids decreases with the increase in temperatures due to Brownian motions of the nanofluids lessens the cohesive energy.

c) All in all, surface tension of the nanofluids enhances with that of the pure methanols.

More studies are required to develop the models or correlations for prediction of the surface tension effects on nanofluids.
Acknowledgement

"This research is supported by High Impact Research MoE Grant UM.C/625/1/HIR/MoE/ENG/40 from the Ministry of Education Malaysia".

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