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Effect of Concentration and Temperature on Viscosity of Titanium Dioxide Nanofluid in Saltwater as Base Fluid

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Abstract

Rapid development in nanotechnology has produced several aspects for the nanotechnologists to look into. Nanofluid is one of the incredible outcomes of such advancement. They are best known for their remarkable change to enhanced heat transfer abilities. Viscosity is an important flow property of fluids that needs the same attention due to its very crucial impact on heat transfer. In the present work, viscosity of TiO2 nanofluids in saltwater are experimentally investigated to determine their applicability in different temperatures and volume fractions. All measurements have been done over a range of 20–60°C for nanoparticle volumetric concentration of 0.05–0.8%. It was observed that the viscosity of the nanofluid increases with the increasing concentration of TiO2 in the nanofluid. Usually, typical used carrier fluids are water, organic liquids (ethylene glycol, oil, biological liquids, etc.), and polymer solutions and investigation of the nanofluid properties in salt-water as base fluid has been largely overlooked. This has been motivated us by the use of salt-water in this study.

Keywords: Nanofluid; Viscosity; TiO2; Salt-water; Volume fraction

1. Introduction

Nanofluids as a new class of fluids, can prepare by dispersing nanometer-sized materials in the form of nanotubes, nanofibers, nanoparticles, nanowires, into the base fluid, that have low values of thermophysical properties like thermal conductivity, thermal diffusivity, viscosity, etc. Numerous researches have shown the effects of nanofluids in heat transfer equipments. But, one of the most challenges is the increase in viscosity due to the suspension of nanoparticles. This is not desirable in the industry, especially when it involves flow, such as in heat exchanger or micro-channel applications where lowering pressure drop and pumping power are of significance. In this regard, study of the parameters which can affect viscosity of nanofluids is very necessary. Studies on viscosity have been reported by numerous researchers. Several researchers observed a Newtonian behavior, while a non-Newtonian behavior was found by other researchers [1-6]. Some authors have also developed models to describe the rheological behavior of nanofluids. Koo [7] introduced a model to predict the thermal conductivity and viscosity of nanofluid in terms of nanoparticle size, concentration and density. Masoumi et al. [8] also presented a model to calculate the effective viscosity by considering the Brownian motion and the relative viscosity between the fluid and particles. Murshed et al. [9] measured thermal conductivity of TiO2 water nanofluids with cetyl trimethtl ammonium bromide (CTAB) surfactant at ambient temperature and revealed very higher conductivity values, if compared with our results at the same temperature and in respect to the Hamilton and Crosser model. Zhang et al. [10] reported conductivity measurement on TiO2 water nanofluids at 283 K, 303 K and 313 K at low concentrations. Duangthongsuk and Wongwises [11] studied thermal conductivity of TiO2 water nanofluids at temperature ranging between 288 K and 308 K. However, a comparison with literature data is not easy because many parameters affecting nanofluid behavior are not available in the papers. Moreover, fluids containing the same particles can exhibit different behaviors. An exact study shows that the effective viscosity of nanofluids depends on a variety of factors such as surface chemistry of the particles, concentration of nanoparticles, the size and shape of particles, base fluid, pH, temperature, and the preparation method. These factors affect strongly the properties and morphology of suspension of nanoparticles/nanofluids [12, 13] by changing the structure of electrical double layer around particles/ aggregates [14] and the interaction between particles/aggregates due to attractive van der Waals force and DLVO forces [15]. With respect to the flow behavior of nanofluid plays a vital role in designing of heat transfer equipments, the experimental study of viscosity of nanofluids which depend on base fluid properties, type of nanoparticles, temperature and particle volume fraction is now a challenging task. For this reason, this research reports the measured viscosity data on TiO2-salt-water nanofluids in the concentration range of 0.05-0.8 vol %. The novelty of the work is using salt-water as base fluid.

2. Results and Discussion

Viscosity is an important property of nanofluids for all thermal applications involving fluid flows, because it characterizes the inertial resistance when fluid flows in the pipe or other system. Thus quantitative information of viscosity of nanofluids is necessary for industrial applications to establish adequate pumping power as well as the convective heat transfer coefficient. In this research work, effect of five volume fractions of TiO2 nanoparticles (0. 05 to 0.8%) in temperature ranges 20 – 60 °C on variations of viscosity of nanofluids in saltwater has been studied. All experimental data analyzed and showed that the viscosity can vary with volume fraction of nanoparticles and temperature. The volume fraction is the percentage of volume of nanoparticles to the mixture volume of base fluid (salt-water) with nanoparticles. Probe-type sonicators and bath sonicators were used to homogenize the suspensions to break particle agglomerates. Viscosity of TiO2 at different temperatures and concentrations is illustrated in Figure 1.

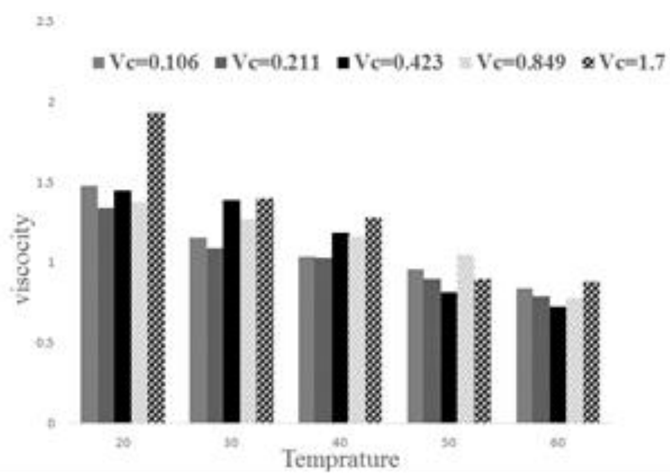

Figure 1- The corresponding values of viscosity with different vol.% of TiO_2 nanoparticles as a function of temperature

It is clear that the rise in temperature results in reduced viscosity and addition of volume fraction also results in higher viscosity. The viscosity increases up to the concentration of 0.8 vol %. The figure shows a maximum in viscosity at 20 °C and volume fraction 0.8% and a minimum for volume fraction 0.2% at 60 °C. The viscosity of nanofluids is mainly dependent on the concentration of nanoparticles, properties of base fluid and temperatures well as the size of the nanoparticles. From the results of the current study we can see that there is not an organized trend between viscosity, volume fraction and temperature. This is because TiO2 nanofluid is not stable, and due to the high rate of aggregation, sedimentation of nanoparticles takes place and consequently no organization is observed. The TEM image confirms this suggestion in figure 2. volume fraction and temperature. This is because TiO_2 nanofluid is not stable, and due to the high rate of aggregation, sedimentation of nanoparticles takes place and consequently no organization is observed. The TEM image confirm this suggestion in figure 2.

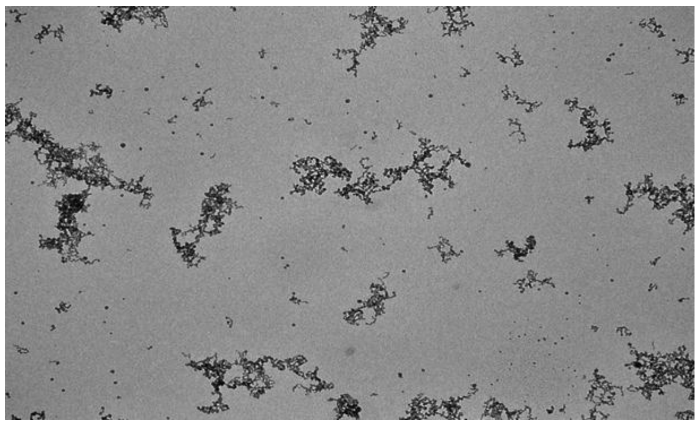

Figure 2 -TEM image of titanium dioxide nanofluid in high viscosity

The reason that the Newtonian viscosity of a fluid is mostly modified to be non-Newtonian in colloidal suspensions is related to the complex interactions between the fluid and particles as well as particles themselves. Recently, it has been reported that there are possible particle aggregations and formation of larger structures through linking of nanoparticles in nanofluids [16,17]. The viscosity of nanofluids has been affected by the aggregations where the sizes of aggregates are between 3 and 4 times the diameter of nanoparticles. It seems that the existence of aggregation process can be responsible for the present results. In addition, due to the Van der Waals forces between nanoparticles, they can coagulate to form agglomerates. In this case the structure of nanofluids may resemble the structure of polymer solutions. From this point of view, it is not surprising that at high concentrations of nanoparticles, nanofluid become non-Newtonian. It is suggested that nano TiO2 particles are much more subject to form aggregates or superstructures. Indicating strong possibility that nanofluid may be non-Newtonian. It seems that the enhancement in viscosity does not only depend on the temperature, but also primarily on the volume concentration [18].

3. Experimental

Titanium dioxide nanopowder with particle size 20-30 nm, were synthesized by sol-gel method in our laboratory (Figure 3).

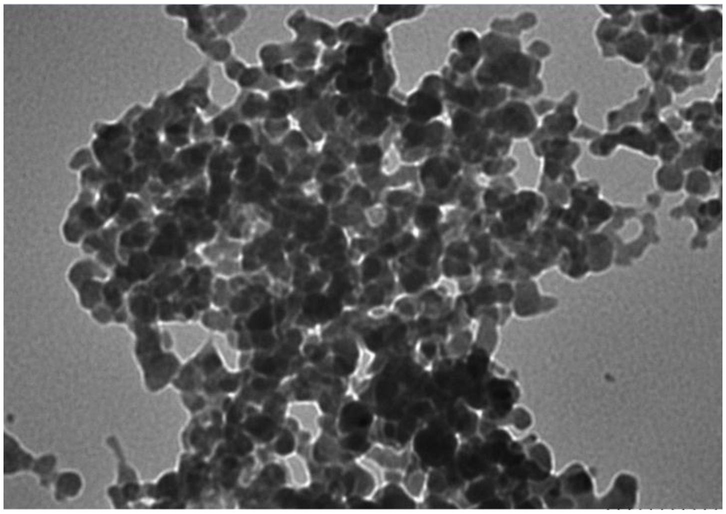

Figure 3- TEM image of synthesized TiO_2 nanoparticles by sol-gel method

Deionized water was used to prepare the nanofluids. The nanofluid was characterized by transmission electron microscopy (CM120 Philips Holland). To evaluate the viscosity a commercial Brookfield DV-I prime viscometer is used to measure the viscosity at different temperatures. The base fluid (salt-water) has been used to measure the viscosity for calibration, after which nanofluids are used to measure the viscosity. The TiO2 nanofluids were synthesized by two-step method. TiO2 nanoparticles, with an average size 20-30 nm were dispersed in salt-water (300 ppm) as base fluid with different percent volume fractions of TiO2 (0.05, 0.1, 0.2, 0.4 and 0.8 vol%). Bulk density of anatase TiO2 used in the present study is 4230 kg/m3 with a specific surface area of 200-240- m2/g and 99% purity. The density of deionized water used is 996.9 kg/m3 at 298.15 K. To obtain well dispersed nanofluids, the pH value of distilled water was first adjusted to~3 using standard HCl 0.1 M solutions. The mixture was then stirred for 60 minutes and after that is sonicated for 2×45 minutes by using probe sonicater and bath sonicater (Figures 4 and 5).

Figure 4 - TiO_2 nanofluids under sonication by probe sonicator

Figure 5- TiO_2 nanofluids under sonication by bath sonicator

The nanofluids were found to be stable for over a month (Figure 6).

Figure 6 - TiO_2 nanofluid after 4 weeks

4. Conclusions

In the present study, the viscosity of five types of TiO2 nanofluids in salt- water has been measured experimentally. The nanofluids were prepared in volume concentrations of 0.05, 0.1, 0.2, 0.4 and 0.8 vol. %. The measured viscosity data showed that the viscosity of nanofluids significantly decreases with increasing temperature, and increases with increasing particle volume concentration. Regarding the viscosity data, the results indicated that the measured data are quite different from those obtained by other investigators, which may a result of various parameters such as the particle preparation, particle size, measurement technique or even the different particle sources [19-21].

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6. References

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