CE-403: RHEOLOGY BASED ON SUSPENSION CONTAINING TITANIUM DIOXIDE

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Abstract

Due to a high demand of an advanced in heat transfer application for an optimal plant performance, numerous researchers conducted research on heat transfer and flow behaviour of nanofluid in order to meet the expectation of the industry needs. However, there has been claimed that the stability and flow behaviour of nanofluid has become a drawback to its application in heat transfer enhancement. This research focuses on the determination of the rheological behavior of nanofluids when titania (TiO_2) nanoparticles are suspended in deionized water. Nanofluid was formulated by using two-step method. The stability of nanofluid as a function of pH and surfactant were evaluated by using sedimentation method and FE-SEM was employed to analyze morphology of nanoparticles. From the results obtained, pH and surfactant affected the stability of nanofluid greatly. Based on rheology of nanofluids, behavior such as Newtonian and non-Newtonian behavior can be predicted. The rheological behaviour was observed to be affected by several main parameters which include temperature, concentration of titania, and concentration of surfactant. From this research, it was found that titania in deionized water exhibit non-Newtonian behaviour. Subsequently the viscosity of nanofluids was observed to be a function of particle loading, pH and temperature. All in all, the stability and rheological behaviour of nanofluid is proven not to be a disadvantage to the potential of nanofluid application.

Key word: *Heat transfer, Nanofluids, Non-Newtonian, Titania, Viscosity*

INTRODUCTION

This research focuses on, the rheological behavior of nanofluids when titania (TiO_2) nanoparticles are suspended in deionized water. There are several factors that lead the usage of titania for this study. First and foremost is titania nanoparticles have been produced in large industrial scale. Besides, in these days, titania is considered as a safe material for human and animals as well. On the other hand, metal oxides likes TiO_2 are more stable rather than their metallic counterparts. The rheological behaviour actually is affected by several main factors which include particle size and shape,temperature and particle concentrations. Based on previous studies, it is found that temperature give strong effect towards shear viscosity of nanofluids. For particle size, the viscosity will show tendency to depend on volume fraction when the size is decreased (Zhao *et al.*, 2006). Meanwhile, nanofluids containing rod-like particles are likely to have high viscosity rather than spherical nanoparticles (Chen *et al*., 2009).

In point of fact, stability of nanoparticles as well as uniform dispersion in the liquids play an important roles in nearly all applications of nanofluids. This is because final property of nanofluids are evaluated by the quality and how good the dispersion and suspension of nanofluids. As for that reason, there are many techniques that can be done in order to improve the quality of dispersion and suspension of nanofluids which include mixing of dipersants, surface treatment of nanoparticles and ultrasonication treatment (Duan *et al.*, 2011). From these methods, particle aggregration in the base fluid can be minimized.

The main purpose of this research is to investigate the rheological behaviour of TiO_2 nanoparticles suspended in deionized water. In reality, only several researchers have published particularly on rheological behaviour of nanofluid. In addition, due to few publications on this subject, there are inconsistencies in determining the nanofluids rheological behaviour. Some have reported that TiO_2-deionized water based tend to show Newtonian behavior and vice versa (Chen *et al.* (2007). So, it is still unclear either TiO_2-deionized water show Newtonian behavior or non-Newtonian behavior.

EXPERIMENTAL METHOD

Nanofluids were prepared by using two-step method. Nanofluids with concentration 0.1%, 0.5%, 1.0% and 3.0% were prepared. Titania nanoparticles were added into the 30mL of deionized water based on the concentration desired. Prior to that, titania nanoparticles were treated for about two hour using sonicator. Then, deionized water was added and the sample was stirred for about one hour. NaOH and HCl were added to the samples to adjust the pH of the samples. The samples were then sonicated for about 30 minutes to ensure homogeneity. To enhance the stability of the nanofluids samples, Sodium Laurate Sulfate (SLS) was added to the samples.

Viscosity measurement was done on all the nanofluids samples. The samples were heated up to several temperatures to investigate the effects of temperature on viscosity. Temperatures used for this test were 27°C, 40°C and 60°C.

RESULTS AND DISCUSSION

Morphology of TiO_2 Nanoparticles

Information on the composition of individual particle can be done by some analysis using FE-SEM (Field Emission Scanning Electron Microscopy). This instrument actually can produce clearer and less electrostatically distorted image. Figure 1 shows image of nanoparticles by using FE-SEM. The average nanoparticles size was between 25-40 nm. It can be said that the nanoparticles was spherical in shape.

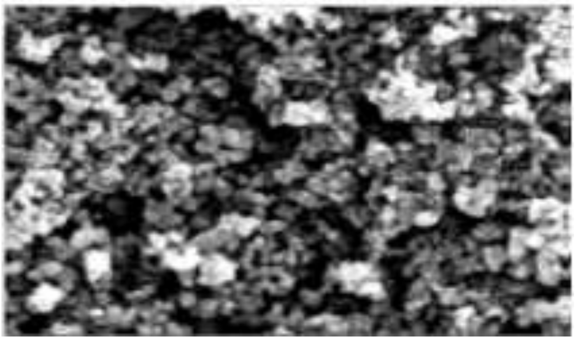


Figure 1: FE-SEM image of TiO_2 nanoparticle

1. Stability of Nanofluids

In this research, titania (TiO_2) nanoparticles were dispersed in 30 mL deionized water. Four particles loading corresponded approximately to 0.1%, 0.5%, 1.0% and 3.0% TiO_2 nanoparticles were prepared at pH 3, pH 4, pH 10, pH 11 and the initial pH of nanofluids. All samples were observed at stationary state over a period of time. Nanofluids that remained suspended were considered as stable and were selected for further analysis. The most stable nanofluids was observed for samples with pH 3 and pH 11.

The addition of SLS also have proved to enhance the stability of nanofluids. SLS is an anionic surfactant which partially ionized to form anionic species. The negative charge of surfactant is not enough to balance the positive charge of titania. Therefore, the tendency for particles to reunion is high thus nanofluids are less stable. SLS is a carbon chain that consists of hydrophobic and hydrophilic ion. It is noted that hydrophobic ion is one of the factor that cause reunion of particles. The amount of surfactant added is sufficient enough to balance positive and negative charge. Thus excess of surfactant will be adsorbed on the surface and surface will be covered with dispersant molecules. Thus, it results in increasing thickness of electric double layer, so, repulsion forces are very strong enough to avoid reunion and deagglomeration of particles.

Viscosity Measurement

There are several effects that influence viscosity of nanofluids. In this research effect of parameters such as concentration of TiO_2 and temperature were investigated.

1. Effect of Concentration

Figure 2 shows viscosity of nanofluids at different concentration of nanofluids and pH. It can be said that viscosity of nanofluids increase as a result of increment in concentration of TiO_2 nanofluids. Even at different pH, similar trend can be seen.

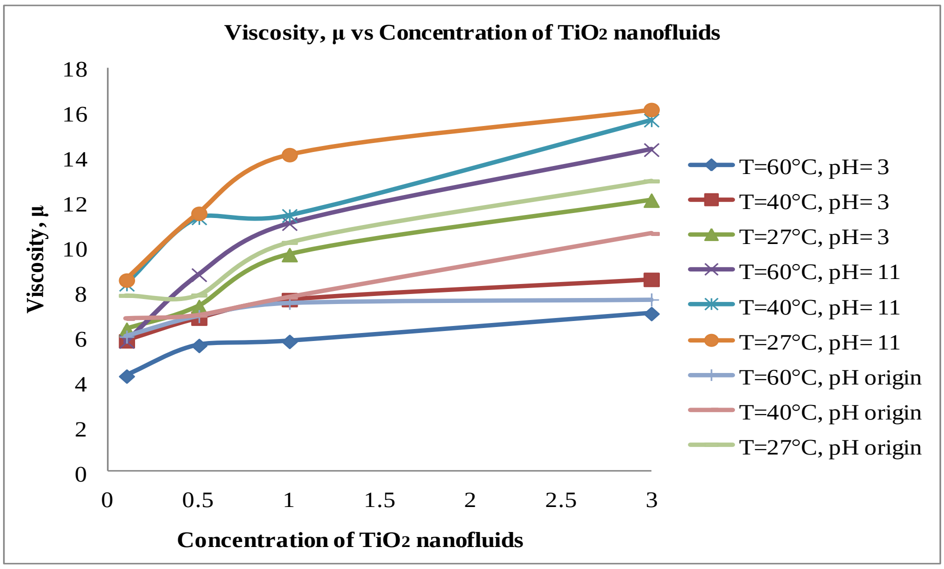


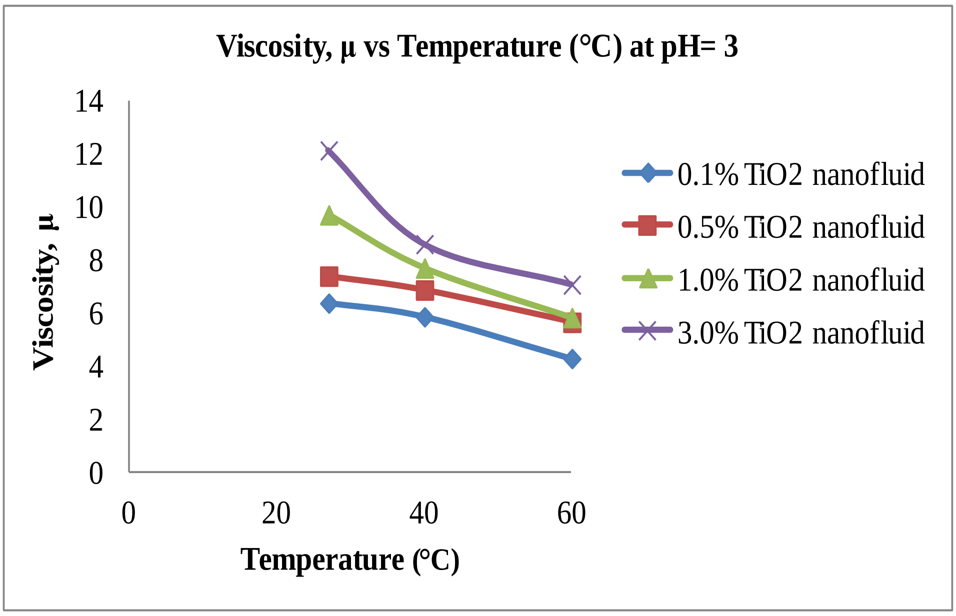
Figure 2: Viscosity TiO_2-deionized water nanofluids at different pH and temperature

Rising in dynamic viscosity probably occur because of nanoparticle agglomeration. As the particle concentration increases, the interparticle interaction decreases, thus these particles less mobilized. Therefore, the liquid become more viscous. Similar observation was reported by Tseng and Lin (2003) and

2. Effect of Temperature

Duangthongsuk *et al.*, (2009) had stated that viscosity of nanofluids increased when temperature decreased, meanwhile, the viscosity showed in increment as a result of increasing in volume fraction. Same result was obtained by Chen *et al.*, (2009) which explained temperature is one of the major factor that influence the viscosity measurement with higher temperature lead to stronger shear thinning.

Figure 3 shows the viscosity against temperature profile at different pH. It shows that the viscosity decreased with increasing temperature. The results obtained were similar with what had been deduced by Duangthongsuk *et al.*(2009), and Chen *et al.*(2009). As the temperature increase, the heat causes the particles to speed up as they collide and move around to each other which means the kinetic energy for particles in the fluid tend to increase as well. The greater kinetic energy of particles, the easier for the nanoparticles to overcome attraction forces which hold the particles together. As a result, less viscous of nanofluids is obtained at high temperature. In addition, more movement among the particles signifies the fluids thin out and it become more liquidy. Based on thee graphs, it shows that viscosity decrease as increasing in temperature which means that nanofluids shows shear-thinning behaviour.



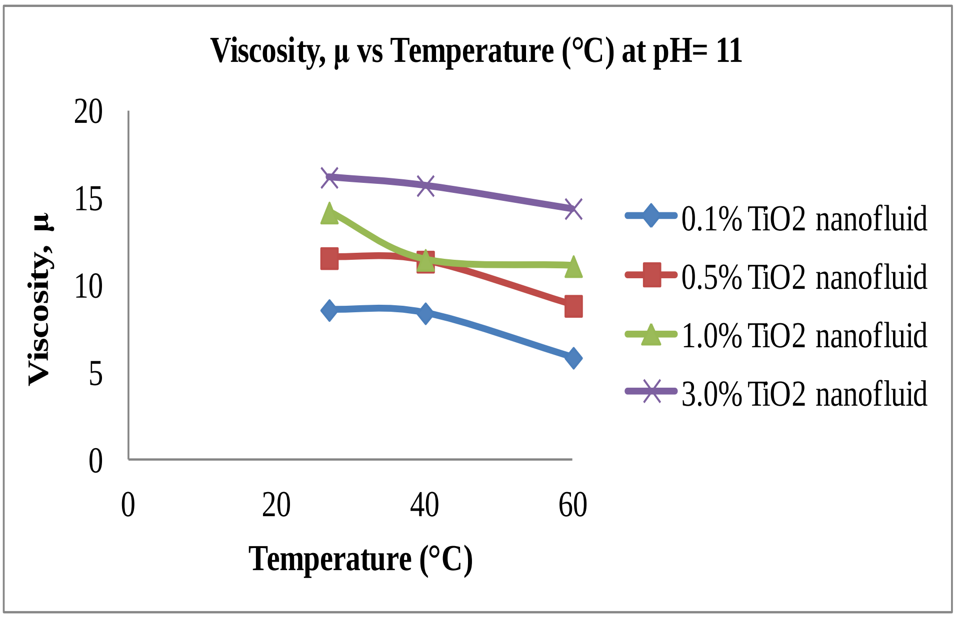


Figure 3: Viscosity of TiO2-deionized water nanofluids at different temperature

From the viscosity analysis, it can be indicated that titania-water based nanofluids exhibit non-Newtonian behaviour. It can be said that since titania based water exhibit non-Newtonian behaviour, it dominates the rheological property and thus whole mixture behaves like non-Newtonian fluids.

CONCLUSION

Stable nanofluids can be formulated using two-step method. The stability can be enhanced with the aid of pH modification and addition of surfactant. The viscosity measurements have shown that the nanofluids tend to exhibit non-Newtonian behaviour.

REFERENCES

1. Chen, H., Ding, Y., and Tan, C. (2007). Rheological Behaviour of Nanofluids. *New Journal of Physics*. 9, 1-25.

2. Chen, H., Ding, Y., Lapkin, A., and Fan, X. (2009). Rheological Behaviour of Ethylene Glycol-Titanate. *Journal of Nanoparticle Research.* 11(6), 1513-1520.

3. Duan, F., Kwek, D., and Crivoi, A. (2011). Viscosity Affected by Nanoparticles Aggregation in Al_2O_3-Water Nanofluids. *Nanoscale Research Letters* 6:248.

4. Duangthongsuk, W. and Wongwises, S. (2009). Measurement Of Temperature-Dependent Thermal Conductivity And Viscosity Of TiO2-Water Nanofluids. Experimental Thermal and Fluid Science. 3, 706-714

5. Tseng, W.J. and Lin, K.C. (2003). Rheological and colloidal structure of aqueous TiO2 nanoparticle suspensions, Materials Science and Engineering, A355, 186-192.

6. Zhao, J.F, Luo, Z.Y, Ni, M.J. and Cen, K.F. (2006). Dependence of Nanofluid Viscosity on Particle Size and pH Value. Chinese Physics Letters. 26 (6): 066202