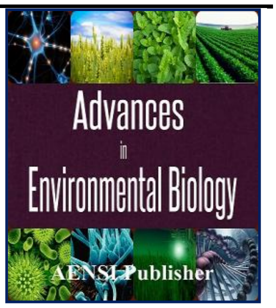
**Advances in Environmental Biology**, 9(21) Special 2015, Pages: 43-47

AENSI Journals

**Advances in Environmental Biology**

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/




# Thermal and Flow Behaviour of Titania-Deionized Water Nanofluids

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**ARTICLE INFO**

***Article history:***
*Received 23 July 2015*
*Accepted 25 August 2015*
*Available online 5 September 2015*

***Keywords:***
*nanofluids; thermal conductivity; viscosity*

**ABSTRACT**

In this research, the properties and characteristics of $TiO_2$-Ethylene glycol nanofluids was investigated. The nanofluids was prepared using two-step method with the aid of Polyvinylpyrrolidone (PVP) as stabilizing agent. The effect of temperature and concentration on viscosity and thermal conductivity were studied. The different concentrations of nanofluids were tested over a temperature range of 30˚C-60˚C. The thermal conductivity was measured using thermal analyzer device that employes the hot-wire method. Thermal conductivity enhancement was observed for the nanofluids. It was also found that the surface chemistry (pH value) also affects thermopysical properties and rheological behaviour of nanofluids. The dynamic viscosity of nanofluids was measured using calibrated viscometer on cylindrical measurement chamber. The results showed that viscosity increases with increasing nanoparticles concentration. As temperature increases, the kinetic energy of nanoparticles will also increase and thus causes each nanoparticle to collide with higher frequency. This prevents the attraction forces between nanoparticles at the same time prevent agglomerations. The nanofluids showed shear thinning behavior.



**To Cite This Article:** Hajar Alias, Anwar Johari, Norzita Ngadi and Muhd Zakwan Zaine., Thermal and Flow Behaviour of Titania-Deionized Water Nanofluids. ***Adv. Environ. Biol., 9(21),*** *43-47, 2015*

## INTRODUCTION

Nanofluids is a new term of heat fluids consist of nanometer-sized particle dispersed in base fluid. Nanofluids is dilute liquid suspension of nanoparticles containing dimensions smaller than 100 nm [1]. Nanofluids have attracted great interest in research since the report of the ability of great thermal properties. Past research stated that nanofluids have significantly better heat characteristics compared to the base fluids. Nanofluids have indicated increases in thermal conductivity as well as convective heat transfer coefficient compared with liquids without nanoparticles. Masuda *et al*. [2] studied the thermophysical properties of the metallic oxide particles ($Al_2O_3$ and $TiO_2$) dispersed in water. The transient hot-wire method was used for measuring the thermal conductivity of nanofluids. They reported that the thermal conductivity of nanofluids was significantly higher than the base liquid. For example, the thermal conductivity of $Al_2O_3$-water nanofluids and $TiO_2$-water nanofluids at a 4.3 vol.% were approximately 32% and 11% higher than that of base liquid, respectively.

Chandrasekar *et al*. [3] described that the thermal conductivity and viscosity of nanofluids increased with the nanoparticle volume concentration. Besides that, based on studies of static thermal conductivity, heat transfer and flow behaviour of stable aqueous $TiO_2$ by Turgut *et al*. [4], it was found that thermal conductivity increased with an increase of particle volume fraction, and the enhancement was observed to be 7.4% over the base fluid for nanofluids with 3% volume fraction of $TiO_2$ nanoparticles at 13°C. The thermal conductivity of suspended $TiO_2$ nanoparticles in Deionized Water and results showed that the thermal conductivity of nanofluids increased with increasing volume fraction of nanoparticles [5]. From this investigation, it shows that the nanoparticles showed great achievement in increasing the efficiency of thermal transport. In addition, the dynamic viscosity has been found to increase with increasing particle concentration in the nanofluids. Viscosity can be described as internal resistance of a fluid to flow, thus this factor could cause several side effects in heat transfer studies especially with nanofluids with higher particle loading use as heat transfer fluids

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since past research proved that enhancement of viscosity can decrease the usage of nanofluids as heat transfer fluids [6].

This study was conducted to meet the following objectives: i) to prepare stable nanofluids containing titania particle in deionized water (DW) with acidic solution, ii) to to investigate the flow behaviour in terms of rheology, and iii) to measure the thermal conductivity of nanofluids at various temperature and different particle concentration.

## MATERIALS AND METHODOLOGY

Basically, the raw materials that was used for the preparation of stable titania nanofluids were titania nanoparticles ($TiO_2$), deionized water (DW), hydrochloric acid (HCl), sodium hydroxide (NaOH) and surfactant which is polyvinylpyrrolidone (PVP). Meanwhile pH meter was used in order to measure the pH of the nanofluids samples. Brookfield Viscometer DV-II+ Pro were used to measure the value of viscosity. The KD2 Pro, Decagon Devices Inc. thermal property analyser was used to measure thermal conductivity of nanofluids.

### *Synthesis of Titania Nanofluids:*

Good formulation of nanofluids is the key factor to ensure the optimum properties and characteristics of nanofluids. Two-step method of the nanofluids preparation was applied. Titania nanoparticles in powder form was dispersed in DW base fluids with different particles concentration (0.1, 0.5, 1.0, 5.0, 10.0 wt.%). 0.5% of PVP surfactant is used to assist the dispersion of the titania nanoparticle in DW. The pH of the samples was adjusted to ing HCl.

### *Viscosity Measurement:*

Viscosity was measured for rheological properties of titania-DW based nanofluids. The Brookfield Viscometer DV-II+ Pro device with data acquisition system was used to measure the viscosity of nanofluids samples at different temperatures of 27°C, 40°C, 50°C and 60°C. The viscosity test used Rheocalc software for data acquisition.

### *Thermal Conductivity Measurement:*

The thermal conductivity of the nanofluids was measured by thermal property analyser, KD2 Pro, Decagon Devices Inc. All $TiO_2$-DW based nanofluids in acidic state including pure DW sample was measured at temperature of 27°C, 40°C, 50°C and 60°C. Hot water bath and heating plate was used to increase the temperature of samples at 40°C, 50°C and 60°C.

## RESULTS AND DISCUSSION

### *Stability Investigation of Nanofluids:*

The stability of the nanofluids was observed for any sign of sedimentation over a certain period of time. The samples were left at stationary state and those that remained suspended were considered to have high stability [6]. Figure 1 shows the $TiO_2$-DW nanofluids after a week of experiment. Stability of nanofluids is essential to ensure the efficiency of heat transfer in flow system.

**Fig. 1:** Samples of $TiO_2$-DW based nanofluids with PVP.

Nanofluids can lose its performance for heat transfer due to agglomeration of nanoparticles in the base fluid. The addition of PVP obviously enhance the stabilization of $TiO_2$-DW nanofluids. Optimum amount of surfactant is crucial to ensure the thermos-physical properties of nanofluids is within the appropriate value for the application and not to increase the frictional factor of the fluids. Too much of surfactant will increase the viscosity and thus will result in low performance of heat transfer

### *Rheological Studies of Nanofluids:*

The viscosities of the $TiO_2$-DW based nanofluid was measured at different ranging of temperatures at 27°C, 40°C, 50°C and 60°C by using Brookfield Viscometer DV-II+ Pro device equipment. Figure 2 shows the viscosity of nanofluids at 27°C. It shows that the nanofluids exhibits shear thinning behavior. The viscosity increases as the nanoparticles concentration increases. As reported in the literature, the shear-thinning effect, in addition to the effect of nanoparticles size, can be attributed to the disagglomeration of the nanoparticles clusters and the alignment of the agglomerates and nanoparticles during shear, resulting in less viscous force [7].

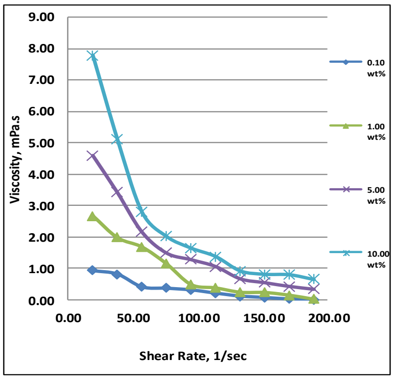


**Fig. 2:** Viscosity of nanofluids at 27°C.

Figure 3 shows the viscosity of nanofluids at different temperature. The viscosity decreased with increasing temperature. From these results, it can be proved that the viscosity of a solution such as nanofluids decreases as the temperature of the solution was increased. It was also supported by past research that reported the viscosity of nanofluids decreases with the increase of temperature [8]. Besides that, the results also shows good agreement with the measured data from past research [4] which showed that, for a temperature range of 13 to 55°C at volume fraction of 0.2–3%, nanofluids viscosity decreased with the increased of temperature. In addition, research by Duangthongsuk and Wongwises [9] also showed that the viscosity of nanofluids decreased with the increase of temperatures. Furthermore, for a given concentration, density data showed temperature dependences similar to the base fluid; decreasing with temperature.

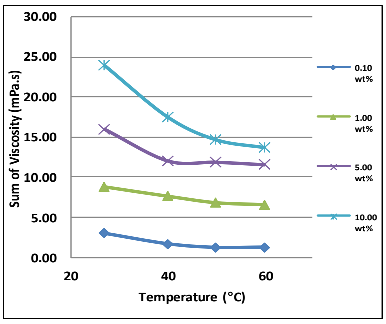


**Fig. 3:** Viscosity of nanofluids at different temperature.

*Thermal Conductivity of Nanofluids:*

Thermal conductivity of TiO2-DW nanofluids was conducted at temperatures of 27°C, 40°C, 50°C and 60°C. Figure 4 shows the thermal conductivity of $TiO_2$-DW nanofluids as a function of particle concentration and temperature. The results show that the thermal conductivity of nanofluids significantly increases with increasing nanoparticle concentration. The same behavior was observed in previous research [4]. Thus, it can be verified that thermal conductivity of nanofluids increases with nanoparticle in the nanofluids.

The thermal conductivity of nanofluids also substantially increases with increasing temperature of the nanofluids. Thermal conductivity of nanofluids also substantially increases with increasing temperature of the nanofluids. The results also show good agreement with the research data by Kim *et al.* [11]

Lots of research studies have focused on pH have influences of zeta potential, particle size distribution, rheology, viscosity, and stability on heat transfer nanofluids as well as the thermal conductivity of nanofluids. Figure 5 shows the thermal conductivity of $TiO_2$-DW based nanofluids samples at different pH condition. It shows that, the thermal conductivity of sample at pH = 11 was higher compared to the sample at pH = 3.

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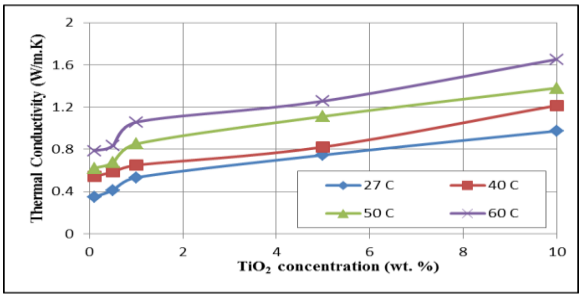


**Fig. 4:** Thermal conductivity of nanofluids at different temperatures.

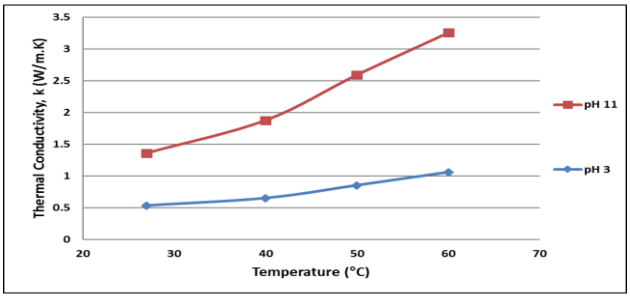


**Figure 5.** Thermal conductivity of $TiO_2$-DW base fluid at different pH.

Based on research conducted by Zhu *et al*. [12], it stated that the measurement of thermal conductivity ratio for $Al_2O_3$ water based nanofluids with addition of SDBS dispersant as a function of pH shows increments in thermal conductivity ratio with increment of pH from 3.0 to 8.0 – 9.0. Therefore, it strongly supported the measured data results which stated that the thermal conductivity increase with an increment in pH value of nanofluids.

There are some cases that the effect of pH can lowered down the thermal conductivity of nanofluids. Based on research by Wang *et al*. [13], at lower pH, the thermal conductivity ratio for water based Cu and $Al_2O_3$ nanofluids was found to decrease at higher pH. It was concluded that an optimal pH value can result in the highest thermal conductivity of the nanofluids.

*Conclusion:*

In this study, the synthesis of the stable Deionized water (DW) based nanofluids containing titania was successfully conducted. The nanofluids remained suspended over a week and thus, it can be concluded that the function of PVP as surfactant may be significant. The investigation of flow behaviour of nanofluids showed that the viscosity tend to increase with addition of particle concentration and decrease with increments of temperature. In addition, from the measurement of thermal conductivity, the results showed that, thermal conductivity of $TiO_2$-DW nanofluids increased with increment of particle concentration and temperature of nanofluids. Thermal conductivity was also found to be affected by pH.

## ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi Malaysia for the Research University (RU) grant vot Q.J130000.2544.08H62 for funding the research.

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