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Experimental Study of Thermophysical Properties of TiO_2 Nanofluid

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Abstract

Titanium-dioxide (TiO_2) nanoparticles suspended in water, and ethanol based fluids have been prepared using one step method and characterized by scanning electron microscopy (SEM), and UV–visible spectrophotometer. The TiO_2 nanoparticles were added to base fluids with different volume concentrations from 0.1% to1.5% by dispersing the synthesized nanoparticles in deionized water and ethanol solutions. The effective thermal conductivity, viscosity and pH of prepared nanofluids at different temperatures from 15 to 30 ^oC were carried out and investigated. It was observed that the thermal conductivity, pH, and viscosity of nanofluids increases with the increase in TiO_2 nanoparticle volume fraction. The thermal conductivity of TiO_2 nanofluids significantly increases linearly with increasing particle vol. fraction at different temperature values and also it was found that the viscosity increases with increasing particle vol. fraction and decreases with the increase in temperature.

Key Words: Nanofluids, Thermal conductivity, Viscosity, TiO_2 nanoparticles.

Introduction

Nanofluids are engineered by suspending nanoparticles with common sizes below 100 nm in conventional heat transfer fluids such as water, oil, and ethylene glycol.

Improvements in the thermal properties of base fluids, was indicated when an extremely small amount of nanoparticles dispersed regularly and suspended stably in base fluids. Nanofluid is the term introduced by Choi [1] to express this novel class of nanotechnology-based heat transfer fluids that exhibit thermal properties better than those of their host fluids or conventional particle fluid suspensions.

Titanium-dioxide (TiO_2) is one of the most paying attention materials in nanoscience and nanotechnology because of having a lot of attractive properties from fundamental and practical point of view by Castillo et al. [2]. Titanium-dioxide is present in three crystal forms: rutile, anatase and brookite; where the rutile and anatase phases have higher practical utility.

Yoo et al. [3] showed that the presence of nanoparticles of TiO_2, Al_2O_3, and Fe in base fluid caused a large enhancement in thermal conductivity compared to their base fluid. Kim et al. [4] have calculated the thermal conductivity of ZnO and TiO_2 nanoparticals in base fluid (water and ethylene glycol). The experimental data showed the effects of both particle size and volume concentration on thermal conductivity.

In the present study the thermophysical properties of TiO_2 nanoparticles in base fluids of deionized water and ethanol in the temperature ranges of 15-30^{o}C at different volume concentrations of nanoparticles (0.1, 0.5,1 and 1.5%) was investigated.

Experimental

1- Preparation of Nanofluids

Titanium dioxide nanoparticles, anatase, with an average diameter of 13 nm were used in the present work (ordered form USA nanomaterials co.) [5]. TiO_2 nanoparticles with different volume concentrations (0. 1%, 0.5%, 1%, 1.5%) were dispersed in DDW (denoized water) and ethanol based fluids. The suspensions of nanofluids were then stirred and agitated thoroughly for 15 min with an ultrasonic homogenizer. This ensures uniform dispersion of nanoparticles in the base fluid. Table 1 shows the physical properties of TiO_2 nanoparticles.

Table 1, Properties of TiO_2 Nanoparticle

Average particle diameter, nm	13
Purity, %	99.99
Density, kg/m^3	3900
Color	White

2- Thermophysical Properties and Characterization of Tio_2 Based Nanofluids

Thermal conductivity was measured using a thermal conductivity meter (KD2 Pro, Decagon device, USA). A viscometer (Fungilab) was used for viscosity measurement. pH was measured using a pocket-sized pH meter with replaceable electrode (InolabpH7110), TiO_2 nanopaticles were characterized by using SEM model (FEI). UV-visible (model UVWIN5 Spectrophotometer) was used to show the absorption spectroscopy or reflectance spectroscopy in the ultraviolet-visible spectral region.

Fig. (1) shows the SEM micrograph of the TiO_2 nanoparticles. The micrograph shows that the particles have nearly spherical shape and uniformly distributed. Larger particles may be aggregates of the smaller ones.

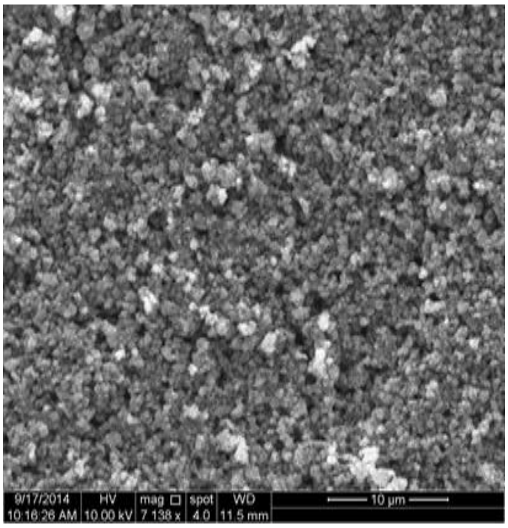

Fig. 1, SEM Morphology of TiO_2 NPs

The energy dispersive X-ray analysis (EDX) image of the TiO_2 nanoparticles was recorded in the binding energy region of 0–20 keV as shown in Fig. (2).

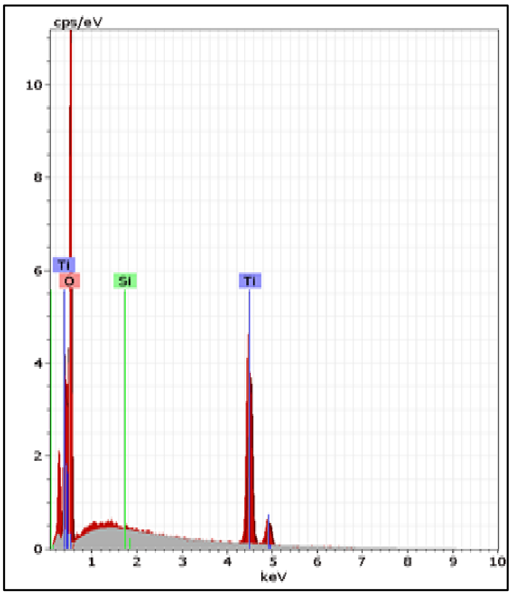

Fig. 2, EDX image of TiO_2 NPs

The peak from the spectrum reveals the presence of Ti and O at 4.5 and 0.6 keV respectively.

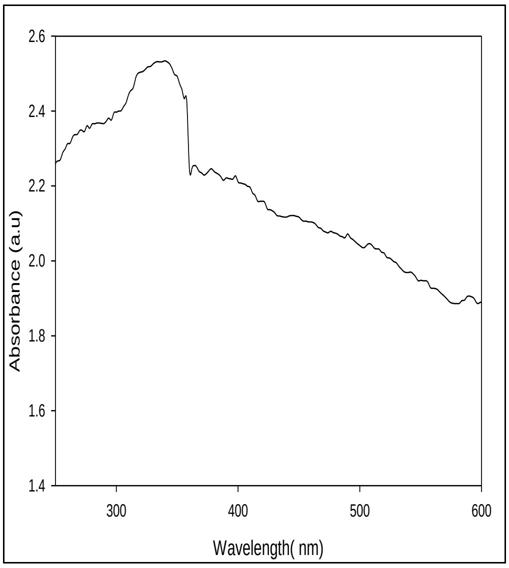

Fig. 3, UV-vis Absorption Spectrum of TiO_2/DDWnanofluids

The present composition of Ti and O reveals the formation of non-stoichometric TiO_2 which is superior for photocatalytic applications. The absorption spectrum of TiO_2 nanoparticles was measured by UV–Visible absorption spectrometry. Fig. (3) shows the variation of optical absorbance with wavelength.

The absorption band edges were estimated around 340 nm (about 3.6 eV).

Fig. (4) shows the measured thermal conductivity of TiO_2/DDW nanofluid as a function of TiO_2 nanoparticles volume concentrations at different temperature values. It is observed that the thermal conductivity increases with increasing both TiO_2 volume concentrations and temperature range from 15 to 30 ^{o}C. In addition, the thermal conductivity of nanofluids is nearly constant at low particle concentrations (less than 1% by volume), for example the increase in the thermal conductivity of a 1.5% nanofluids at 20^{o}C is about 39 % whereas it is about 44 % at 30 ^{o}C in case of nanofluids, Brownian motion of nanoparticles causes change of temperature and clustering of nanoparticles, which results in remarkable changes of thermal conductivity of nanofluids with temperature.

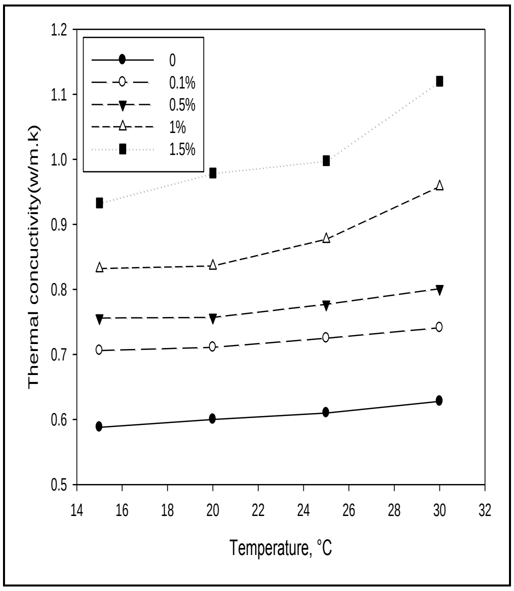

Fig. 4, Thermal conductivity of TiO_2/DDW nanofluids versus temperatures at different TiO_2nanoparticle volume concentration

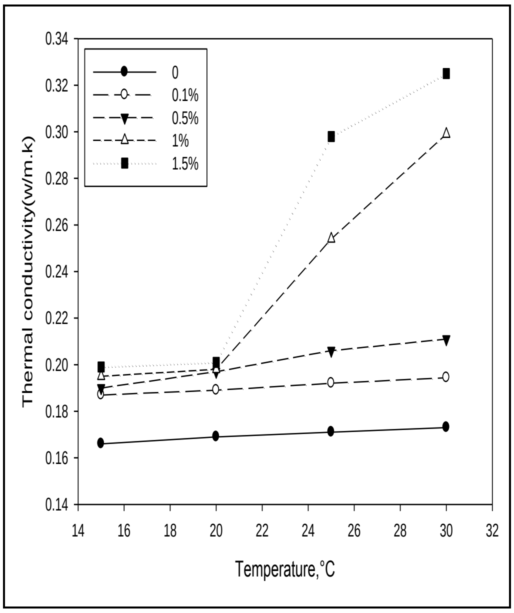

Fig. 5, Thermal conductivity of TiO_2/ethanol nanofluids versus temperatures at different TiO_2 nanoparticle volume concentration

Since water has a higher thermal conductivity than ethanol, any presence of water in ethanol would lead to an increase in the effective thermal conductivity. Therefore, presence of water in ethanol based nanofluids could lead to an erroneous conclusion about the enhancement, which is due to the presence of nanoparticles by Sunder [6]. Differences in the improvement of performance can be attributable to variations of the resistance of thermal boundary about the nanoparticles happening for diverse base fluids [7].

Fig. (6) shows the experimental thermal conductivity results of TiO_2 nanofluids obtained in the experiment in comparison with the three conductivity models by Maxwell, Hamilton and Brugeman show in table (2) below:

Table 2, Effective Thermal Conductivity Correlations for Nanofluids

Reference	Correlation	
Maxwell's	$K_{nf} = K_f + 3\varphi \frac{K_p - k_f}{2k_f + K_p} K_f$	Spherical, low volume fractions, random distributed particles
Hamilton and Crosser	$K_{nf} = \frac{K_p + (n-1)K_f - (n-1)(K_p - K_f)\varphi}{K_p + (n-1)K_f + (K_f - K_p)\varphi}$	Spherical, low volume fractions, random distributed particles, for non-spherical n=6
Bruggeman	$\varphi(\frac{K_p - K_{nf}}{K_p + 2K_{nf}}) + (1-\varphi)(\frac{K_f - K_{nf}}{K_f + 2K_{nf}})$	Binary mixture, homogeneous, no limitations on the concentration, random distributed particles

The thermal conductivity of TiO_2 nanofluids conducted by these three models is far less than the experimental thermal conductivity because the diverse of assumptions used in the experimental such as (spherical particle, no change in particle size and ≤ 1.5% volume concentration) compared with other models in table (2).

The probable parameters which promote thermal conductivity enhancement are stochastic and Brownian motion of nanoparticles in the base fluid. The temperature is another factor which is responsible for particle random movements which in turn results in enhanced thermal conductivity.

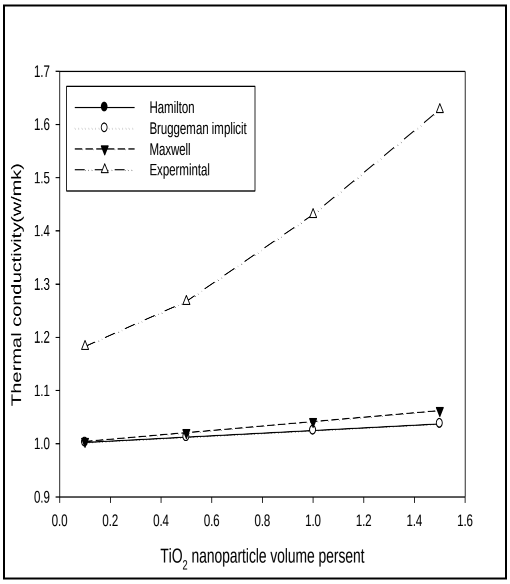

Fig. 6, Comparison between theoretical and experimental behaviour of thermal conductivity of TiO_2 NPs

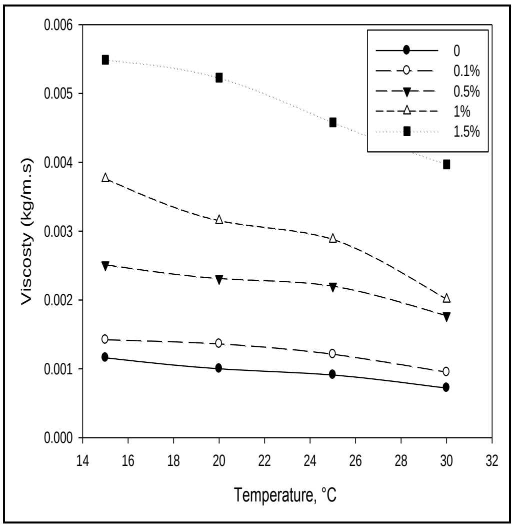

Fig. 7, the viscosity of TiO_2/DDW nanofluids as a function of TiO_2 NPs volume concentration measured at different temperatures

Fig. (7) and (8) show the variation of viscosity value as a function of TiO_2 volume concentration. It is observed that viscosity increases slightly with the increases of TiO_2 volume concentration of nanoparticles in nanofluids (DDW and ethanol). However, the viscosity of nanofluids is significantly higher when compared to base fluid due to presence of nano-sized particles.

At higher temperatures, the forces between the TiO_2 nanoparticles and the base fluid are weakened, causing a decrease in value of viscosity. For example at 1.5% viscosity is 5.49 at 15^{o}C and decrease to3.97 at 30^{o}C.

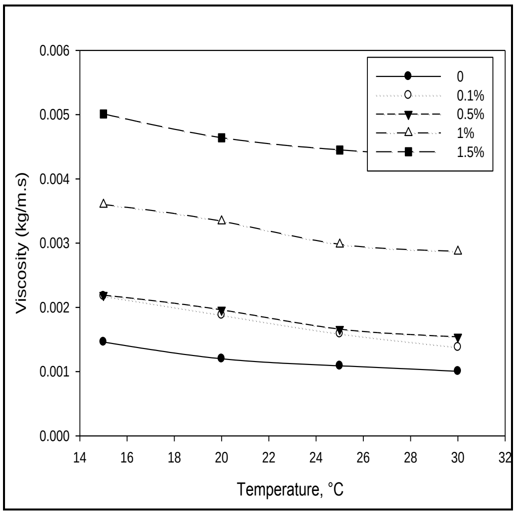

Fig. 8, the viscosity of TiO_2/ethanol nanofluids as a function of TiO_2 NPs volume concentration measured at different temperatures.

Fig. (9) show the variation of pH value of nano-fluids as a function of TiO_2 volume concentration. It was observed that at 1.5% volume concentration of TiO_2 nanoparticles, the pH value decreased to 7.13 in the case of TiO_2/DDW and to 8.2 in the case of TiO_2/ethanol nanofluids. It can be observed that for TiO_2/DDWnanofluid, the pH value decreased from 7.7 at 1% to 7.13 at 1.5% volume concentration of TiO_2 nanoparticles. In the same trend, the pH value decreased from 8.56 to 8.2 accordingly in the case of TiO_2/ethanol nanofluid. This is ascribed to the effects of nanoparticles, which are identified to appearance clusters; this clustering can effect in quick transfer of heat over comparatively great ranges ago heat can be conducted extremely faster before particles of solid when compared to matrix of liquid, by Ravi Babu [8].

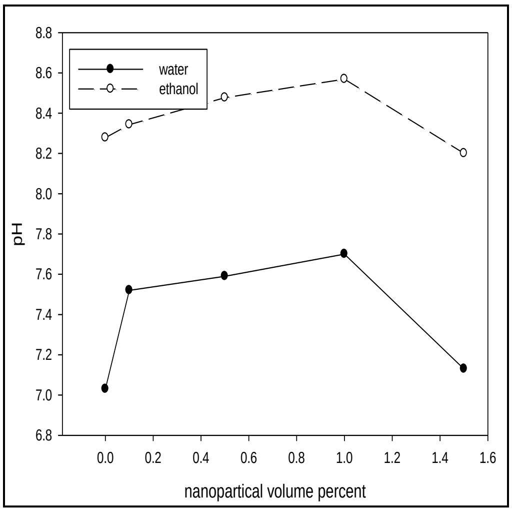

Fig. 9, pH of TiO_2 nanofluids in different base fluids as a function of volume fraction concentration

Conclusions

In this paper the effective thermal conductivities, viscosities and pH of water and ethanol based nanofluids containing TiO_2 nanoparticles are investigated experimental. The presence of TiO_2 nanoparticle in base fluid is capable of enhancement the thermal conductivity of base fluid. The level of the base fluid enhancement depends on the amount of nanoparticle added to base fluid at the concentration of 1.5 vol. %; the thermal conductivity enhancement of 51.1% at 30^oC compared to base fluid was recorded. Also thermal conductivity of nanofluids increases with the increase in temperature. The viscosity of nanofluids was significantly higher as compared to the base fluid for two the nanofluids tested. The viscosity of TiO_2/DDWwas found to be 5.49*10^{-3} kg.m/s at 15^oC and it decreased to 3.97*10^{-3} kg.m/s at 30^oC at a 1.5% TiO_2 nanoparticles.

Reference

1- Choi, S. U. S. ()., Singer, A. and Wang., H. P., 1995, “Enhancing thermal conductivity of fluids with nanoparticles, in Developments and Applications of Non-Newtonian Flows”, American Society of Mechanical Engineers, Vol. 66, p. 99–105.

2- Castillo, N., Olguin, D., Conde G.A., Jiménez, S.S., 2004, “Structural and morphological properties of TiO_2 thin films prepared by spray pyrolysis”, Revista Mexicana De Física50 (4) 382.

3- Yoo, D.H., Hongb, K.S., Yang., H.S., 2006, “Study of thermal conductivity of nanofluids for the application of heat transfer fluids”. ThermochimicaActa, 455, pp.66-69.

4- Kim, S.H., Choi, S.R., Kim,D., 2007, “Thermal conductivity of metal-oxide nanofluids: partical size dependence and effect of laser irradiation”. Transaction of ASME, 129, pp.298-307.

5- US Research Nanomaterials, Inc. The Advanced Nanomaterials Provider 3302 Twig Leaf Lane, Houston, TX 77084, USA Phone: 832-460-3661, Fax: 281-492-8628 E-mail: Service@us-nano.com; Tech@us-nano.com Website: www.us-nano.com

6- Syam, L.,S. , Manoj, K .S., Ramana, E.V. , Singh ,B. , JoséGrácio & Antonio Sousa, C. M., 2014, “Enhanced Thermal Conductivity and Viscosity of Nanodiamond-Nickel NanocompositeNanofluids”, Scientific Reports 4, No.:4039.

7- Asmaa H. D., 2015, “Investigation of Thermal Transport Properties Enhancement of Nanoparticles Suspensions in the Application of Nanofluids”, Ph.D thesis, Baghdad University.

8- Ravi Babu, S., Ramesh, P. B., Dr. Rambabu, V., 2013, “Effects of Some Parameters on Thermal Conductivity of Nanofluids and Mechanisms of Heat Transfer Improvement”, International Journal of Engineering Research and Applications (IJERA), Issue 4, Vol. 3, pp. 2136-2140.