IJAAR PUBLISHING®

Engineering Research Journal | ISSN: 2782-8212
Vol. 3, Issue 11 (November, 2023) | www.ijaar.org/erj

DETERMINATION OF ELECTRICAL AND THERMAL CONDUCTIVITIES OF NANOFLUID PRODUCED FROM PALM KERNEL SHELLS NANOPARTICLES

BY

Engr. Ogenyi A. Daniel

Department of Mechanical Engineering Benue State Polytechnic, Ugbokolo

Abstract

The enhancement of thermal conductivity in fluid flows in engineering equipment enhances cooling and increases the life span of such equipment. This study prepared nanoparticles from palm kernel shells. The two step method was used to prepare the nanofluid with deionized water as the basefluid. The study investigated both the electrical and thermal conductivities of the fluid and compared with that of the basefluid to determine their enhancements. The study also evaluated the nanofluid heat transfer characteristics. The effects of volume fractions and the size of particles were also investigated. Results showed that there is a nearly linear rise in electrical conductivity of the nanofluids with particle volume fraction and a significant increase in electrical conductivity enhancement was also observed. The thermal conductivity of the nanofluids also increased as the temperature and concentration of the respective volume fractions increased. The thermal conductivity enhancement increases as the volume fraction increases with the highest enhancement of 5.60% for 0.5% volume fraction. According to this research, palm kernel shells based nanofluid have the potentials to be used as an alternative to metallic oxides to produce nanofluid for heat transfer enhancement in engineering equipment for cooling purposes.

Keywords: Nanofluid, Palm kernel shells, Electrical conductivity, Thermal conductivity, Volume fraction

.

30/11/2023
Ogenyi, A.D. (2023). Determination of Electrical and Thermal Conductivities of Nanofluid Produced from Palm Kernel Shells Nanoparticles. *Engineering Research Journal*, 3(11), 14-28.

I. INTRODUCTION

Solid particles dispersed fluid improve heat transfer co-efficient of the fluid, nanoparticles have been used to replace the micrometer or millimeter-sized particles which tend to settle rapidly, clog flow channels, erode pipelines and cause severe pressure drops[1]. Suspension of nanometer size particles or fibres dispersed in a liquid (basefluid) is none as nanofluid. These particles are suspended by Brownian motions as a result when compared to the base fluid, change in physical properties of such mixture occurs

Electrical conductivity of a nanofluid can be related to the ability of charged particles (ions) in the suspension to carry the charges (electrons) towards respective electrodes when an electric potential is applied. In nanofluids, the nanoparticles dispersed in a base fluid get charged due to the formation of electrical double layer around the particle surface [2]. Thus, Electrical conductivity is an important parameter for characterization of nanofluids and it needs similar attention as thermal conductivity of nanofluids as the most commonly used thermal conductivity measurement method of transient hot wire gets significantly affected by the electrical conductivity of nanofluids.

Only a few studies have been reported on the electrical conductivity of nanofluids. The two-step approach was used, during investigation on a long-multiwalled carbon nanotube with distilled water as basefluid [3]. Samples between 0.01 and 3 wt were sonicated for 50min and 2 wt. % gum Arabic (GA) was added as surfactant to the nanofluid samples. The results showed that at 0.01 wt. % the electrical conductivity was 0.35μS/cm and it was increased with an increase of concentration of the nanoparticles in the base fluid. The electrical conductivity at 0.1wt % was about 0.448μS/cm. However, at 2 and 3 wt. % there was no significant change in electrical conductivity where the electrical conductivity was between 0.454 and 0.453μS/cm, respectively. The enhancement of electrical conductivity of the nanofluid, comparing to base fluid was 18%. In similar vein [4] investigated the Single-walled carbon nanotubes in a mixture of 50% deionized water and 50% ethylene glycol with concentrations between 0.05 and 0.5 wt. % of SWNCT. The increase of the electrical conductivity was from 0.12×10^{-3} to 1.7×10^{-3} S/m for 0 and 0.5 wt. % respectively.

Heris et al., [5] prepared aluminum oxide nanofluids with deionized water as basefluid. They noticed that the nanofluid samples were stable for several days without appearance sedimentation. The results showed that the electrical conductivity of alumina was increased almost linearly by increasing of volume fraction of alumina nanoparticles. Also the electrical conductivity was used as function of temperature where a highly temperature gave a high electrical conductivity. They also determine the rate of enhancement of the electrical conductivity by getting the difference between the electrical conductivity of a nanofluid and the electrical conductivity of the base fluid divided by the electrical conductivity of the base fluid for all volume fractions of nanofluid. Results showed that the enhancement increases with increase of volume fraction and temperature. They determined the Electrical conductivity enhancement as

$$E_k = \frac{Ecnf - Ecbf}{Ecbf} \quad (1)$$

Where,
E_k is the electrical conductivity enhancement
Ecnf is the electrical conductivity of nanofluid

Ecbf is the electrical conductivity of basefluid

The electrical conductivity of nanofluids containing metallic and ceramic particles (Cu, Al_2O_3, and CuO) increases with increasing particle concentration and reducing particle size [6]. They argued that the effective dielectric constant and density are at the root of the counter intuitive observation that the electrical conductivity enhancement of ceramic nanofluids is more than that of metal-based ones which is substantiated by the Clausius–Mossotti relation for the polar fluids. They also found that the influence of surfactant increases the stability and decreases the electrical conductivity of the nanofluids by increasing its viscosity.

Measurement of Thermal Conductivity

Thermal conductivity is the most important parameter responsible for enhanced heat transfer, many experimental works have been reported on this aspect. The transient hot wire method[7], the steady-state parallel-plate technique [8] and the temperature oscillation technique [9] have been employed to measure the thermal conductivity of nanofluids. Among these the transient hot wire method has been used most extensively. Because in general nanofluids are electrically conductive, it is difficult to apply the ordinary transient hot-wire technique directly. A modified hot-wire cell and electrical system was proposed by [10] by coating the hot wire with an epoxy adhesive which has excellent electrical insulation and heat conduction.

The thermal conductivity enhancement for each volume fraction is calculated based on the equation

$$E_k = \frac{K_{nf} - K_{bf}}{K_{bf}} \text{ x } 100 \quad (2)$$

Where:

E_k is the thermal conductivity enhancement

K_{nf} is thermal conductivity of the nanofluid and K_{bf} is thermal conductivity of the base fluid

It had been reported that possible concentration of ions of the conducting fluids around the hot wire may affect the accuracy of such experimental results [9]. The oscillation method was proposed by [11] and further developed by [12]. This method is purely thermal and the electrical components of the apparatus are removed from the test sample. Hence ion movement should not affect the measurement. Alumina (Al_2O_3) and copper oxide are the most common and inexpensive nanoparticles used by many researchers in their experimental investigations. All the experimental results have demonstrated the enhancement of the thermal conductivity by addition of nanoparticles.

Investigation on the thermal conductivity of nanofluids containing Al_2O_3, CuO, and Cu nanoparticles with two different base fluids: water and HE-200 oil was carried out [13]. A 60% improvement of the thermal conductivity was achieved as compared to the corresponding base fluids for only 5 vol% of nanoparticles. They also showed that the use of Cu nanoparticles (using the one-step method) results in greater improvements than that of CuO (using the two-step

method). [14] suspended CuO and Al_2O3 (18.6 and 23.6 nm, 24.4 and 38.4 nm, respectively) in two different base fluids: water and ethylene glycol (EG) and obtained four combinations of nanofluids: CuO in water, CuO in EG, Al_2O_3 in water and Al_2O_3 in EG. Their experimental results showed that nanofluids have substantially higher thermal Conductivities than the same liquids without nanoparticles. The CuO/EG mixture showed enhancement of more than 20% at 4 vol% of nanoparticles. In the low volume fraction range (<0.05% in test), the thermal conductivity ratios increase almost linearly with volume fraction. Results suggest that not only particle shape but size is considered to be dominant in enhancing the thermal conductivity of nanofluids.

The effective thermal conductivity of nanofluids was measured using steady-state parallel-plate technique [15]. The base fluids (water, ethylene glycol (EG), vacuum pump oil and engine oil) contained suspended Al_2O_3 and CuO nanoparticles of 28 and 23 nm average diameters, respectively. Experimental results demonstrated that the thermal conductivities of all nanofluids were higher than those of their base fluids. Also, comparison with various data indicated that the thermal conductivity of nanofluids increases with decreasing particles size. Results demonstrated 12% improvement of the effective thermal conductivity at 3 vol% of nanoparticles as compared to 20% improvement reported by masuda et al [16] and 8% reported by Xuan and Li [17] at the same volume fraction of particles.

Xuan and Li [18], enhanced the thermal conductivity of water using Cu particles of comparatively large size (100 nm) to the same extent as has been found using CuO particles of much smaller dimension (36 nm). An appropriate selection of dispersants may improve the stability of the suspension. They used oleic acid for transformer oil- Cu nanofluids and laurate salt for water-Cu suspension in their study and found that Cu particles in transformer oil had superior characteristics to the suspension of Cu particles in water.

The past decade has seen many research activities in the experimental heat transfer characteristics of various nanofluids. For forced convective heat transfer, [20] studied the heat transfer behavior in parallel channels using an unspecified nanofluid and observed a reduction in thermal resistance by a factor of 2.

II RELATED WORKS

Research into the use of biomass for the production of bio-inspired synthesis nanofluids has been investigated due to toxicity and high cost of production of nanoparticles produced from metallic oxides. The Preparation, Stability and Viscosity of Nanofluid Produced from Mango Bark (Mangifera Indica) Fibres was reported by [21]. [22] investigated the thermo-physical properties of nanofluids prepared from palm kernel fibres with the aim of improving the thermal conductivity of the basefluid. They used ethylene glycol with deionized water in the ratio of 40:60 as basefluid and established that palm kernel is environmentally friendly with enhanced thermal conductivity properties. They recommended that it can be used as an alternative source for nanofluid production to enhance heat transfer. Similarly, [23] also investigated the use of banana fibre nanoparticles for the production of nanofluid for heat transfer enhancement. Deionized water was used as basefluid. They reported 35 % enhancement. Barki et al [24] investigated on the Electrical Conductivity and pH of Mango Bark (*Mangifera Indica*) Based Nanofluid

This study is aimed at studying the electrical and thermal conductivities of nanofluid produce from palm kernel shells nanoparticles. The study also investigated the thermophysical properties of nanofluid produced from palm kernel shells nanoparticles, the electrical and thermal conductivities enhancements and the effect of volume fraction and temperature on the thermophysical properties of *mangifera indica* nanoparticles based nanofluid

III. MATERIALS AND METHODS

A. Preparation of Nanoparticles

The residues seeds from the preparation of palm oil were used for the experiment. The seeds were cracked to remove the endosperms. The endocarps were used as specimen for the experiment. The specimen was washed with sodium hydroxide to remove the oil content. It was also washed with distilled water to remove impurities and sun dried to eliminate moisture. The dried specimens were stored in polythene sacks to avoid rehydration of the samples awaiting milling. Specimens were taken to Federal Institute of Industrial Research Oshodi, Lagos State, Nigeria for processing into nanoparticles. The 87002 LIMOGE-FRANCE ball milling machine was used for the process. The materials were charged into the machine and milled. The discharge was sieved with nanoparticle sieves to obtain nanoparticles. The nanoparticles were collected in polyethene air-sealed containers.

B. Preparation of Nanofluid

The two-step method was used for the preparation of the nanofluid. This involved the dispersion of the nanoparticle produced from palm kernel shells into a basefluid (de-ionized water) at the department of Mechanical and Aeronautic Engineering, University of Pretoria South Africa. Using a 2001N, 24kHzHielscher ultrasonic processor (up200s) the nanoparticles were dispersed in the basefluid and ultrasonicated for one hour for uniform dispersion of the nanoparticles and breakdown of the agglomerated particles of the nanoplarticles. Agglomeration of the nanoparticles may have taken place during the process of drying, storage, and transportation of the nanoparticles. It has the effect of settlement and clogging of micro channels and can result to a decrease in thermal conductivity of the fluid [25].

Different masses of the sample were measured using a digital highland HCB 1002 (Max:1000g and precision:0.01g) weighing balance and dispersed in the basefluid (De-ionized water). During the ultrasonication, the fluid was kept in a LaudaProune RP1840 water bath. The programmable thermal bath was maintained at room temperature during the ultrasonication period to maintain the properties of the nanofluid. Evaluation of the stability of the nanofluid at different temperatures was done by visual inspection and use of UV spectrum.

C. Electrical conductivity

The electrical conductivity was measured using CON 700 conductivity / ^{0}c / ^{0}f electrode meter. The experimental set up is as shown in plate 1. The instrument was calibrated with DI water at 20 ^{0}C. The electrode of the meter was dipped in the measuring sample of the DI water and the temperature of the sample was regulated by a programmable water bath. The temperature of the water bath was varied between 10 ^{0}C to 60 ^{0}C and the electrical conductivity of the DI water was recorded accordingly with the instantaneous temperature. The electrode meter gives both

temperature and electric conductivity values simultaneously at a given instant. The electrode meter measures the electrical conductivity in µs.

Different volume fraction of nanofluid produced from palm kernel shells was used to investigate their electrical conductivity. 0.1- 0.5 % volume fractions were used for the investigation. Each volume fraction was transferred to the measuring cup and the meter electrode was dipped in the sample. The samples were stirred regularly to maintain uniform temperature in the sample and corresponding values of electrical conductivity recorded.

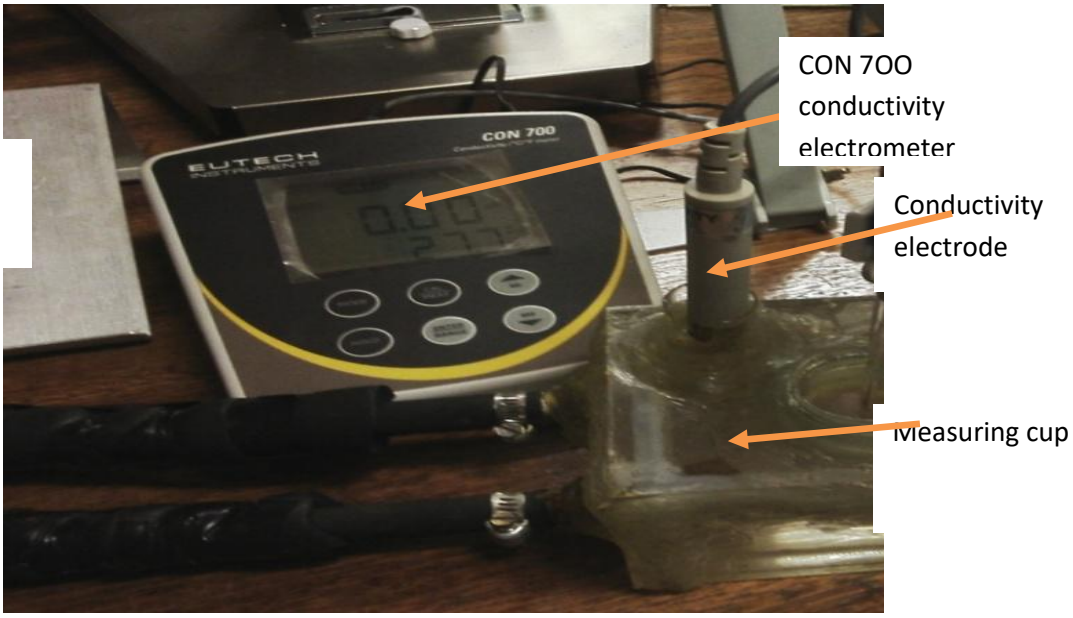


Plate 1: The CON 700 conductivity / ^{0}C / ^{0}F electrode Meter for Measuring Electrical Conductivity

D. **Thermal conductivity measurement**

The KD2 pro which works on the basis of a transient hot wire was used for the thermal conductivity measurement. Plate 2 below shows the apparatus for the measurement. The KD2 pro is a hard held device used to measure thermal properties. The KD 2 pro package consists of a hand held controller and one sensor kit. The single needle sensors measure thermal conductivity and resistivity of a material. It has a thermal conductivity accuracy of ± 5 % and measure thermal conductivity at a range of 0.1 W/mK to 4.0 W/mK. The KD2 pro gathers data for compacting thermal properties. It applies heat to the sensor for half of the set time and takes measurements over the full time. It waits thirty seconds for temperature equilibration before heating starts. The sensor takes sixty temperature reading during the read time and value displays at the right hand corner of screen.

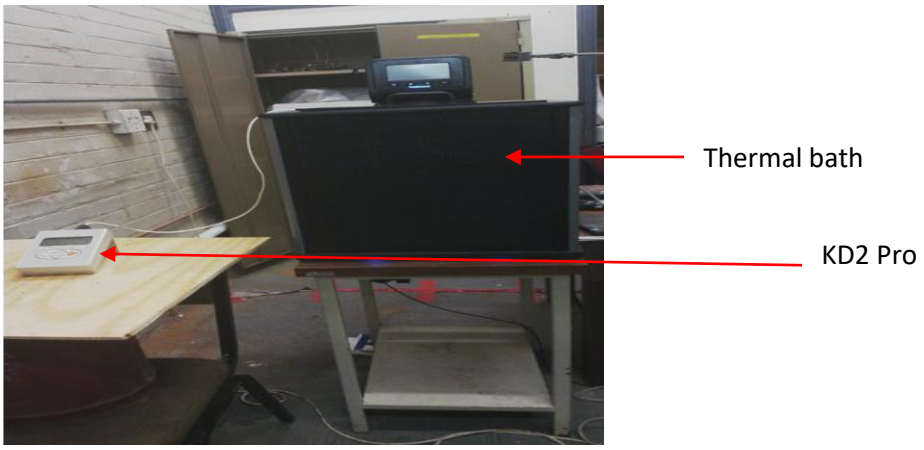


Plate 2: **Experimental Set Up for Thermal Conductivity Measurement using KD2 Pro**

Experimental set up for measuring the sample's thermal conductivity is as shown in plate 2. A quantity of the basefluid (DI-water) was poured into the specimen bottle of 300 mm diameter. The sensor needle connected to a hand held microcontroller was inserted in the bottle and held tight perpendicular to the wall of the bottle. The bottle was placed in a thermal bath and temperature adjusted between 10 to 60 ^{0}C. Corresponding values of the thermal conductivity were recorded. The accuracy of the instrument was checked by measuring the thermal conductivity of glycerine provided by the supplier and compared with the thermal conductivity of glycerine from standard readings. Different volume fractions of palm kernel shells based nanofluid were used for the experiment. Each volume fraction of the nanofluid was sonicated for 1 hour and transferred into the experimental bottle and connected to the KD2 pro. The temperature of the water bath was lowered to 7 ^{0}C and the experimental bottle containing the nanofluid sample was inserted. Then the temperature of the water bath was raised to 10 ^{0}C, maintained at the temperature for 1 hour to normalize the temperature between the water bath and the sample in the measuring bottle. The KD 2 pro was then switched-on and allowed to read the thermal conductivity for 1 hour. Readings were automatically recorded. The temperature of the bath was then increased to 20 ^{0}C, and allowed to normalize for another 1 hour and another reading of thermal conductivity from the KD2 pro was read for another 1 hour. The same procedure was repeated for temperature of 30, 40, 50 and 60 ^{0}C and for each increase in temperature the corresponding values of thermal conductivity were recorded. The bottle was washed with distilled water, accuracy of the instrument was also checked after experimenting with each volume fraction, then the experiment was repeated for respective volume fractions and corresponding values of the thermal conductivity recorded, exported and saved.

E. **Measurement of thermal conductivity of palm kernel shells nanoparticles**

The thermal conductivity of palm kernel shells nanoparticles were measured using the Guarded Hot Plate apparatus as per IS: 3346 (1980), with thickness varying between 25 mm to 50 mm for thermal conductivity measurement. Two specimens of 50 g each were used in the Guarded Hot Plate apparatus. The specimens were used between the cold and guarded hot plates. One specimen was placed in between hot plate and cold plate placed at lower side of the hot plate and other specimen in between hot plate and cold plate above the hot plate. Power was supplied at a controlled rate and temperature in cold plates at set point was maintained at lower temperature

by circulating liquid in both the cold plate and hot plate with the help of cryostat and compressor. When temperature of hot plate and cold plate were reached to set temperatures, the set temperature of hot plate was controlled and maintained by temperature controller. When the temperature of the guard, central, and cold plates became constant and remained steady, it was assumed that the steady state heat flow condition has been reached. The power consumption and temperature difference of the hot and cold plates were measured and thermal conductivity was determined using the equation 3.

$$K = \frac{VId}{A\Delta T} \quad (3)$$

Where,

V- Voltage in Volt
I – Current in Ampere
d – Sample thickness in meter
A – Area of central hot plate
∇− Difference in temperatures (^{o}C) of hot plate and cold plate

The thermal conductivity values at mean temperature of 60 ^{o}C were measured the nanoparticles and average values of 0.622 W/mK was obtained.

IV. RESULTS AND DISCUSSIONS

Figure 13-15 show the peak absorbance of palm kernel shells nanofluid for 0.1, 0.2 and 0.3 % respectively. It shows that the peak absorbance appears at 311, 317 and 363 nm respectively.

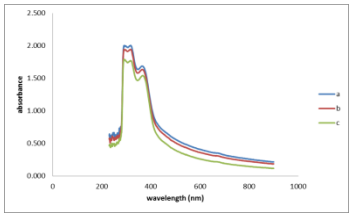


Fig 1a

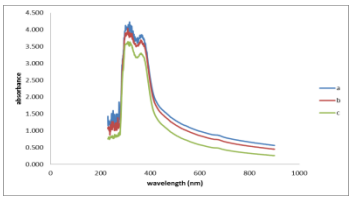


Fig 1b

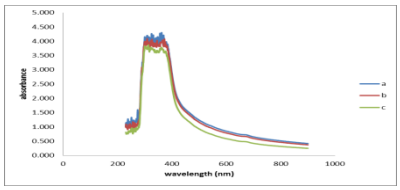


Fig 1c

Figure 1(a,b,c) shows Uv – Vis Spectrum of palm kernel Based Nanofluid for 0.1, 0.2 and 0.3 % Volume Fractions respectively

The broad peaks at respective wavelengths of the various volume fractions represent the formation of small nanoparticles in solution. The trend of the graphs a, b,and c for 0.1 % volume fraction show similar peak for interval of 0hrs, 24hrs and two weeks. The variation in graphs a, b, and c at respective intervals also shows the suspension of the particles in the basefluid at respective times.

Figure 1(a,b,c) shows Uv – Vis Spectrum of palm kernel Based Nanofluid for 0.1, 0.2 and 0.3 % Volume Fractions respectively. Broader peaks were observed for 0.2 and 0.3 % volume fractions (figure b and c) volume fraction at 317 and 363nm respectively. This can also be attributed to more concentration of the nanoparticles in solution. Graphs a, b and c of volume fractions 0.2 and 0.3% have the same trends of broad peaks for intervals of 0hrs, 24hrs and two weeks. This is in agreement with work presented by [25] on determining of stability for metallic oxide based nanofluid.

Figure 2 shows the variation of electrical conductivity with temperature for 0- 0.5% volume fraction for palm kernel base nanofluid. The experiment was carried out on low volume fractions of less than 1.0% as this was the range of good stability during the test for stability. The average electrical conductivities for the volume fractions are: 9.0, 80.9, 144.7, 174.7, 219.5 and 253 µS/cm for volume fractions 0, 0.1, 0.2, 0.3, 0.4 and 0.5 % respectively. This shows that the electrical conductivity of the basefluid is 9.09µS/cm. As nanoparticles of 0.1 % were dispersed in the basefluid the electrical conductivity increased sharply to 80.9 µS/cm. For 0.2 % the electrical conductivity increased to 144.7 %. This shows that the electrical conductivity increases as concentration and temperature increases.

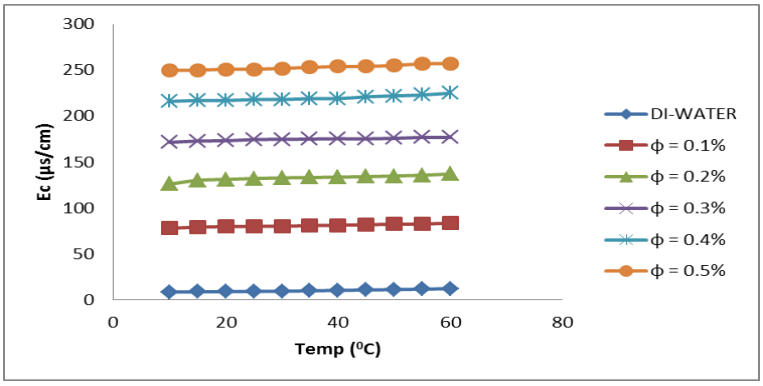


Figure 2: Variation of Electrical Conductivity with Temperature for 0.1 - 0.5 % Volume fraction for palm kernel shells Based Nanofluid

This can be attributed to the fact that increase concentration with temperature in a solution increases the cations and anions in the solution. As a result the distance between cations and anions decreases so that there is more inter-ionic interaction [26].

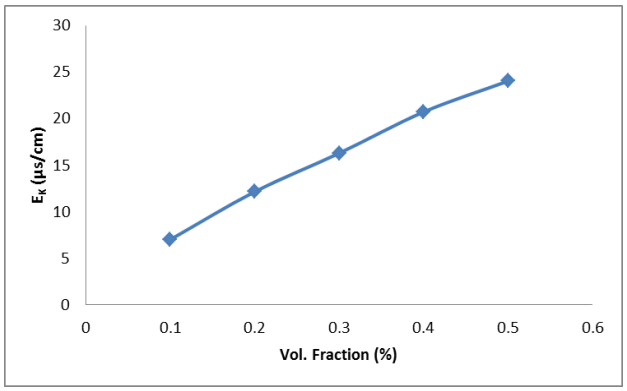


Figure 3: Electrical Conductivity Enhancement for palm kernel **Based Nanofluid**

Figure 3 shows the electrical conductivity enhancements for palm kernel based nanofluid. An enhancement of 7.00 % was observed for 0.1 % volume fraction, 12.14 % for 0.2 %, 16.28 % for 0.3 %, 20.71 % for 0.4 % and 24.03 % for 0.5% volume fractions respectively. Both results showed that the electrical conductivity increased with increase in concentration. It agrees with the works of [27, 28, 29 and 30] where it was established that electrical conductivity increased as concentration increases

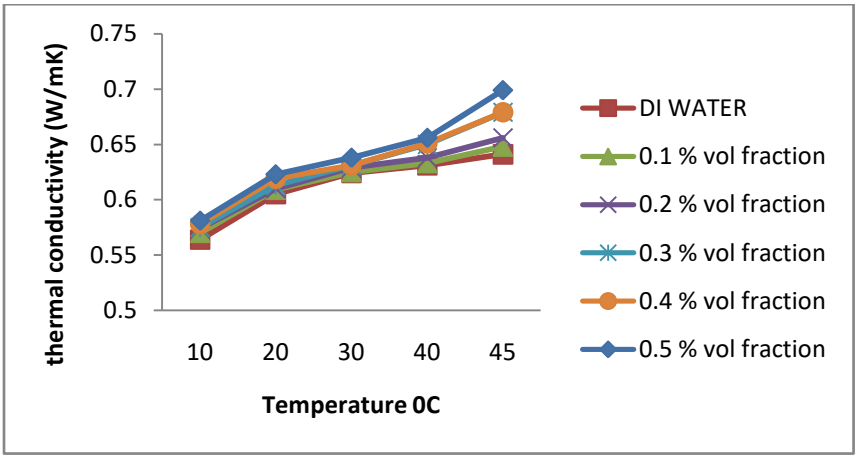


Figure 4: Variation of Thermal Conductivity with Temperature for Various Volume Fractions for palm kernel shells Based Nanofluid

Figure 4 shows the variation of thermal conductivity with temperature for various volume fractions of palm kernel shells based nanofluid. The result shows an increase in thermal conductivity with the dispersion of nanoparticles in the basefluid. The thermal conductivity of de-ionized water at 30 ^{o}C was 0.616 W/mK. At the same temperature, the thermal conductivity of the nanofluid for 0.1 % volume fraction was 0.623 W/mK. There is also increase in the thermal conductivity as the temperature and volume fractions increases. The dependency of thermal conductivity of the nanofluid on temperature can be attributed to onset of Brownian motion at higher temperatures [31]. The random Brownian motion of the suspended nanoparticles disturbs the flow and enhances local mixing. Thus, it is expected that the thermal conductivity of nanofluids will increase sharply with the increase in the suspension temperature. The result of this research disagreed with that of [32 and 33] in their respective researches but agreed with the report of [34].

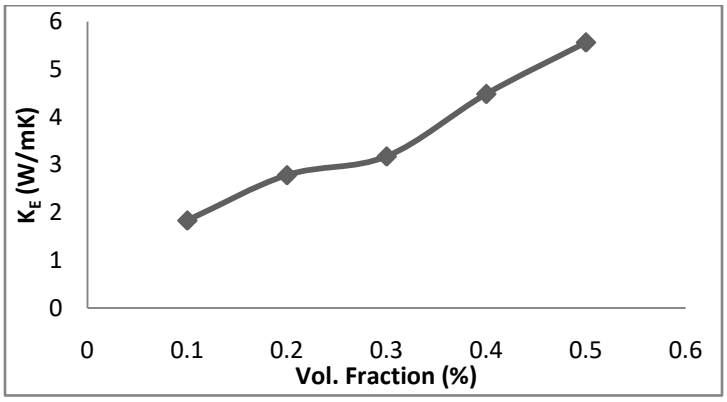


Figure 5: Thermal Conductivity Enhancement of palm kernel **Based Nanofluid for Various Volume Fractions**

Figure 5 shows the thermal conductivity enhancement for palm kernel shell based nanofliud. The equation stated by [35] was used for the determination of each volume fraction thermal

conductivity enhancement. The result shows a 0.34% enhancement for 0.1 % volume fraction. The thermal conductivity enhancement increases as the volume fraction increases with the highest enhancement of 5.6 %.

Many experimental works have been reported on thermal conductivity enhancement that nanofluid enhanced the thermal conductivity of the basefluid. Pang and Yong [34] reported an enhancement of 6.34 % when they observed the thermal conductivity enhancement of 0.1 % volume fraction of Al_2O_3 nanoparticle. Lee et al [14] investigated the thermal enhancement of CuO and Al_2O_3 in water and reported an enhancement of 12 % at 3 % volume fraction using Al_2O_3 and CuO nanoparticles of 28 and 23 nm respectively. Masuda et al [16] reported 20 % improvement; hong et al [3] compared the enhancement of Fe nanofluid with Cu nanofluid at the same volume fraction and observed that Fe nanofluid exhibit a higher enhancement than Cu nanofluid. They concluded that it is not always materials with high thermal conductivity that are always the best candidates for the supervision to improve the thermal characteristics of the basefluid. All the reported works by researchers showed increase in thermal conductivity as the volume fraction increased. This is in agreement with the present work conducted on palm kernel based nanofluids

V. CONCLUSIONS AND FUTURE SCOPE

An investigation into the use of palm kernel shells for the production of nanofluid for heat transfer enhancement has been carried out. The parameters considered in this work were limited to particle volume concentration, temperature, nanoparticle and base fluid and the following conclusions were obtained within the limits of the study conditions.

The choice of nanofluid without the use of surfactant was considered as it shows good stability with no settlement of particles after 2 weeks of observation and for cost effectiveness. It is also shown that there is a nearly linear rise in electrical conductivity of the nanofluids with particle volume fraction and a significant increase in electrical conductivity enhancement was also observed. It has also been established that the thermal conductivity of the nanofluids increased as the temperature and concentration of the respective volume fractions increased. The thermal conductivity enhancement increases as the volume fraction increases with the highest enhancement of 5.60% for 0.5% volume fraction. This trend of behaviour of the nanofluid is in agreement with most works reported in literature for metallic and non- metallic oxide based nanofluids. According to this research, palm kernel shells based nanoparticles have the potentials to be used as an alternative to metallic oxides to produce nanofluid for heat transfer enhancement. However, further research on the stability, viscosity and heat transfer coefficient of the nanofluid can be investigated to authenticate the validity of the potentials of the nanofluid as a substitute for metallic oxide based nanofluid for heat transfer in engineering equipment.

ACKNOWLEDGEMENT

I appreciate Tertiary Education Trust Fund for sponsoring this research work.

REFERENCES

[1] S.W. Lee, S.D. Park and S. Kang, "Investigation of viscosity and thermal conductivity of SiC nanoflinds for heat transfer application". *International Journal of Heat Mass Transfer* vol.**51 pp 433-438, 2011**.

[2] Y. Ding, H. Alias, D. Wen, and R.A. Williams, "Heat transfer of aqueous suspensions of carbon nanotubes (CNT nanofluids)". *International Journal of Heat and Mass Transfer*, **49, pp. 240–250, 2005**

[3] K.Hong, T.K. Hong and H.S. Yang, "Thermal conductivity of Fe nanofluids depending on the cluster size of nanoparticles". *Applied Physics Letters*, **88, no. 3, 31,901–1–3, 2006.**

[4] B. Glover W.W. Keit, H. Haiping, M. Arnab , and W.B. Edward, "Effective Electrical Conductivity of Functional Single Wall Carbon Nanotubes in Aqueous Fluids" . *Synthetic Metals* vol. **158 (12) pp 506 - 508, 2008.**

[5] S. Heris, S.G. Etemad and M. Esfahany. "Experimental investigation of oxide nanofluids laminar flow convective heat transfer". *International Communications in Heat and Mass Transfer*, **33, pp. 529–535, 2006.**

[6] K.G. Kalpana-Sarojini, S.V. Manoj, P.K. Singh, T. Pradeep and S.K. Das, "Electrical Conductivity of Ceramic and Metallic Nanofluids". Colloidal and Surfaces *A. Physicochemical and Engineering Aspects* Vol. **417 Pp 39-46, 2013.**

[7] J. Kestin, and W.A. Wakeham, "A contribution to the theory of the transient hot-wire technique for thermal conductivity measurements". *Physica A,* **92, pp.102–116, 1978.**

[8] J.X. Wang, H.T. Zhu, C.Y. Zhang, Y.M. Tang, B. Ren and Y.S. Yin,"Preparation and thermal conductivity of suspensions of graphite nanoparticles," *Carbon*, vol. **45, pp 226, 2007**

[9] S.K. Das, N. Putta, P. Thiesen, and W. Roetzel, "Temperature dependence of thermal conductivity enhancement for nanofluids". *ASME Trans. Journal. Heat Transfer,* pp. **567–574, 2003**

[10] Y. Nagasaka, and K. Nagashima, "Absolute measurement of the thermal conductivity of electrically conducting liquids by the transient hot-wire method". *Journal of Applied Physics.*, **14, pp.1435–1440. 1981.**

[11] W. Roetzel, S. Prinzen and Y. Xuan, "Measurement of thermal diffusivity using temperature oscillations". In Cremers, C. and Fine, H. (Editors), Thermal conductivity, volume 21 Plenum Press, New York and London , pp. **201–207. 1990**

[12] W. Czarnetzki and W. Roetzel, "Temperature oscillation techniques for simultaneous measurement of thermal diffusivity and conductivity". *International Journal of Thermophysics, **16, pp. 413–422,*** **1995.**

[13] J. A. Eastman, S.U.S Choi, S. Li, W. Yu, and L. J. Thompson, "Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles". *Applied Physics Letters,* **78, pp. 718–720, 2001.**

[14] S. Lee, S.U.S. Choi, S. Li, and J.A. Eastman, "Measuring Thermal Conductivity of Fluids containing Oxide Nanoparticles". *Journal of Heat Transfer,* **121, pp.280–289, 1999.**

[15] J.X. Wang, H.T. Zhu, C.Y. Zhang, Y.M. Tang, B. Ren and Y.S. Yin, "Preparation and thermal conductivity of suspensions of graphite nanoparticles," *Carbon*, vol. **45, pp 226, 2007**

[16] H. Masuda, A. Ebata, K. Teramae and N. Hishinuma, "Alteration of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles (dispersion of -Al_2O_3, SiO_2, and TiO_2 ultra-fine particles)". *Netsu Bussei (Japan),* **7, no. 4, pp.227–233, 1993.**

[17] Y. Xuan, and Q. Li, "Heat Transfer Enhancement of Nanofluids". *International Journal of Heat and Fluid Transfer*, **21, pp.58–64, 2000**

[18]Y. Xuan, and Q. Li, "Investigation on Convective Heat Transfer and Flow Features of Nanofluids". *Journal of Heat Transfer*, **125, pp.151–155, 2003.**

[20] S. Heris, S.G. Etemad and M. Esfahany, "Experimental investigation of oxide nanofluids laminar flow convective heat transfer". *International Communications in Heat and Mass Transfer*, **33, pp. 529–535, 2006.**

[21] E. Barki, J. S. Ibrahim, A. Kuhe and H, A. Iortyer, "Experimental Studies of Viscosity and Stability of Mango Bark (Mangifera Indica) based Nanofluid" 2nd African Conference / Workshop. An International Conference on all aspects of Nanotechnology held at University of Nigeria, Nsukka,Nigeria, **2016.**

[21] J.T. Awua, J.S. Ibrahim, A. Edeoja and A. Kwaghger, Investigation of the thermal conductivity of nanofluid prepared from palm kernel fibre nanoparticles using deionized water and ethylene glycol (60:40) as base fluid. 2nd African Conference / Workshop. An International Conference on all aspects of Nanotechnology held at University of Nigeria, Nsukka,Nigeria, **2016**

[22] U. M. Kallamu, J. Ibrahim, M. Sharifpur and M. Meyer, "Experimental Investigation on Viscosity Of Nanofluids Prepared From Banana Fibre– Nanoparticles," 12th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT **2016**), Costa del Sol, Spain, **2016.**Adio S. A.,

[23] M. Sharifpur and J.P. Meyer, "Influence of Ultrasonication Energy on the Dispersion Consistency of Al_2O_3-Glycerol Nanofluid Based on Viscosity Data, and Model Development for the Required Ultrasonication Density". *Journal of Experimental Nanoscience.* **2015.**

[24] E. Barki, J. S. Ibrahim, A. Kuhe And H, A. Iortyer, Experimental Investigation of Electrical Conductivity and pH of Mango Bark (*Mangifera Indica*) Based Nanofluid, "America Journal of Engineering Research," Vol. **6** Pp. **103-108, 2017**.

[25] S.M.S. Murshed, K.C. Leong and C. Yang, "Characterization of electrokinetic properties of nanofluids". *J. Nanosci nanotechnol* **8(11);5966-5971, 2008.**

[26] B. Glover, W.W. Keith, H. Haiping , M. Arnab and W.B. Edward, "Effective Electrical Conductivity of Functional Single Wall Carbon Nanotubes in Aqueous Fluids". *Synthetic Metals* vol. **158 (12) pp 506 - 508, 2008.**

[27] S. Ganguly, S. Sudipta and B. Somnath, "Experimental Investigation of the Effective Electrical Conductivity of Aluminum Oxide Nanofluids". *Powder Technology* vol. **196 (3) pp 326 -330, 2009.**

[28] K.G. Kalpana-Sarojini, S.V. Manoj, P.K. Singh, T. Pradeep and S.K. Das, "Electrical Conductivity of Ceramic and Metallic Nanofluids". *Colloidal and Surfaces A. Physicochemical and Engineering Aspects* Vol. **417 Pp 39-46, 2013.**

[29] J. Glory, M. Bonetti, M. Helezen, M.M.L. Hermit and C. Reynaud, "Thermal and Electrical Conductivities of Water-based Nanofluids prepared with long Multiwalled Carbon Nanotubes". *Journal of Appl Phys.*vol.**103 pp 303-309, 2008.**

[30] M. Shams, G.Ahmadi and H. Rahimzadeh, "A sublayer model for deposition of nano-and micro-particles in turbulent flows". *Che Eng Sci* **2000, (55) pp6097–6107, 2000.**

[31] A. Turgut, I. Tavman, M. Chirtoc, H.P. Schuchmann, C. Sauter and S. Tavman, "Thermal Conductivity and Viscosity Measurement of Water Based TiO2 Nanofluids". *International Journal of Thermophys*; pp **1-14, 2009.**

[32] C.H. Li, and G.P. Peterson, "Experimental Investigation of Temperature and Volume Fraction Variations on the Effective Thermal Conductivity of Nanoparticle Suspensions (nanofluids)". *Journal of Applied Physics,* **99, no. 8, 084,314, 2006.**

[33] B.C. Lalit and N.C.Ghuge, "Thermo physical properties and heat transfer performance of Ethylene Glycol + water mixture based Al_2O_3 nanofliud; A review". *International journal of science and research (IJSR*) **pp23197064, 2013**.

[34] C. Pang, and K.T. Yong, "Stability and thermal conductivity characteristics of nanofluids (H_2O/CH_3OH + NaCL + Al_2O_3 nanoparticles) for CO_2 absorption application". International refrigeration and air-conditioning conference, paper, **2012**