THERMAL CONDUCTIVITY AND VISCOSITY OF MANGO BARK/WATER NANOFLUIDS

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ABSTRACT

A novel heat transfer fluid with bio-nanomaterial, which is environmentally safe, is prepared and its thermo-physical properties such as thermal conductivity and viscosity are measured. The bio-nanomaterial considered in this study is mango bark. A two-step process is employed to prepare a stable nanofluid. The average particle size was measured using scanning electron microscope and is found to be 100nm. The stability of the nanofluid is checked by measuring the absorbance and viscosity at a constant temperature. The concentration of nanofluid and temperature are varied between 0.1 to 1 vol% and 10 to 60 °C, respectively for the measurement of viscosity and thermal conductivity. The measurement shows that the measured thermal conductivity of the water is comparable with the standard data presented by American Institute of Physics and American Chemical Society. Also, the measured thermal conductivity of the nanofluids showed a slight enhancement compared to the thermal conductivity of water. The measured viscosity of the nanofluids shows exponentially decreasing trend.

INTRODUCTION

In the last few decades, nanofluids have been used in wide areas such as bio-medical, heat transfer, energy, heating buildings and pollution control etc. as the nanofluids possess considerable advantages over the traditional fluids. Though the nanofluids have been used in diversified areas, a special attention is on heat transfer fluids in thermal systems. The concept of nanofluid is well known and is a suspension of ultrafine nanoparticles in traditional fluids [1]. The main advantage of using nanofluids in the thermal system is the exceptional thermo-physical properties such as thermal conductivity, viscosity, surface tension and density. A wide range of research has been done in the past few decades concerning the preparation, stability, and characterisation of nanofluids [2, 3]. All these reviews show the efficacy of nanofluids stability which is a major leap for the design of thermal systems.

NOMENCLATURE

k	[W/mK]	Thermal conductivity
ϕ	[-]	concentration

Subscripts

bf	Base fluid
nf	nanofluid
np	nanoparticle

After that, considering the major interest in the thermo-physical properties of nanofluids which is used in thermal systems, thermal conductivity and viscosity of different kinds of nanofluids were studied. Aybar et al. [4] reviewed the thermal conductivity enhancement in the nanofluids and all of the studies referred show the enhancement in thermal conductivity. A review of viscosity by Mishra et al. [5] suggested that the viscosity is also an important property and it needs the same attention as thermal conductivity since it is a crucial factor for heat transfer enhancement. Thereafter, Meyer et al. [6] reviewed the viscosity of the nanofluids including the literature related to model development and numerical analysis. From this review, it was understood that the volume fraction, particle shape and size, and factors such as temperature and pH were the important factors affecting the viscosity. Apart from the above properties, magnetic field [7-9] also affects the viscosity and thermal conductivity of the magnetic nanofluids. Very recently, Leong et al. [10] reviewed to explore the synthesis method to develop hybrid nanofluids since the thermal conductivity of such nanofluids were better than the single component nanofluids. All these studies suggest that these nanofluids favourable for using in thermal systems

Though many positive effects were found in terms of thermophysical properties in nanofluids, it is believed that the proliferation of nanoparticles to the environment is not safe for humans and environment. Recent studies reveal that the nanoparticles affect the human pulmonary cells [11], human health [12-14], pregnant Mice [15], aquatic organisms [16], animals [17], bacterial growth [18] and environment [19]. From these studies, it is clear that these nanofluids are potentially harmful to the humans and environment. Therefore environmentally safe bio-nanofluids are essential for the safe use of nanofluids and this topic is currently under investigation. In this direction, no such literature are available with the research community. Bio-nanoparticles which are originated from the wood, char, seeds and leaves could be environmentally friendly since naturally humans are exposed to these nanoparticles. Therefore in this study, a new kind of nanofluid consists of bio-nanoparticle is prepared and the thermal conductivity and viscosities are measured for different concentration of nanoparticles at various temperatures.

PREPARATION AND CHARACTERIZATION OF NANOFLUIDS

In this study, nanofluid is prepared using a two-step method. In the first step, the nanoparticle is prepared from the mango bark and leaves by ball milling. Before ball milling, the raw material is dried in the sunlight. In the second step, the prepared nanoparticles are suspended in the De-ionized water (DI water) by using an ultrasonic process. The required volume of nanoparticles is taken and mixed with a necessary amount of water. Then the mixture is subjected to an ultrasonic cavitation (Qsonica-Q700) process for 1 hour to prepare a uniform and stable fluid. After the preparation of nanofluid, the stability of the nanofluids is accessed using UV-Visible spectroscopy (Jenway-7315) and verified with viscosity measurements at constant temperature.

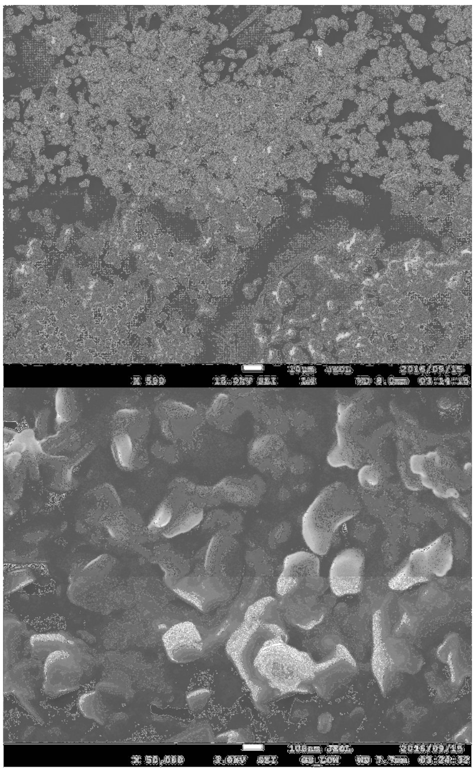

Fig.2 SEM image of mango bark nanoparticles at a magnification of (a) 500X and (b) 50000X

THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS

The thermal conductivity of the nanofluids is measured using KD2 Pro Thermal Property Analyser, Decagon Devices, Inc. The thermal conductivity of nanofluids with the concentration of 0.1 to 1 Vol % is measured at temperatures of 10 to 50^{o}C. The accuracy of the thermal conductivity measurement is ±5%. Also, the viscosities of nanofluids are measured using sine-wave vibro viscometer SV-10 from A&D Company Ltd., Japan. The concentration and temperature of nanofluid are varied between 0.1 to 1 vol% and 10 to 60 ^{o}C, respectively. A proper calibration procedure prescribed by the manufacturers are followed before measurements of both thermal conductivity and viscosity measurements. The measured thermal conductivity of the nanofluids is also compared with the Maxwell correlation [20].

$$k_{nf} = k_{bf}\left[\frac{k_{np}+2k_{bf}-\phi(k_{bf}-k_{np})}{k_{np}+2k_{bf}+\phi(k_{bf}-k_{np})}\right] \quad (1)$$

RESULTS AND DISCUSSION

After the preparation of nanoparticles, the same is characterized using scanning electron microscope. Figure 2 shows the SEM image of nanoparticles and the average particle size is found to be 100 nm. The other properties of prepared nanoparticle are presented in Table 1. After characterization of nanoparticles, nanofluid is prepared as discussed earlier and the stability of the nanofluid is checked by measuring the absorbance and viscosity at a constant temperature. The stability is monitored up to 45 hours and found no change in absorbance or viscosity as shown in Figure 3 which confirms the stability of nanofluids in a prescribed period. Therefore, all the natural convection experiments are completed within 8 hours from the time of nanofluid preparation.

The measured thermal conductivity of the base fluid and nanofluid is presented in figure 4 and also the results are compared with the standard data of water. It is found that the measured thermal conductivity of the water is comparable with the standard data presented by American Institute of Physics and American Chemical Society [21]. Also, the measured thermal conductivity of the nanofluids showed no significant enhancement compared to the thermal conductivity of water. The Maxwell correlation [Ref] also used to predict the thermal conductivity of the nanofluids and it under predicts the experimental results since the thermal conductivity of the wood particles is much less than that of the water.

Figure 5 shows the measured viscosity of the water and nanofluid and comparison with the standard viscosity of water [22]. It is observed that the measured viscosity follows the same trend of standard viscosity. However, it underpredicts the standard viscosity of water. Also, it is noticed that the addition of wood nanoparticles into the traditional fluids does not make much difference in viscosity. However, the measured viscosity showed and exponential variation with temperature.

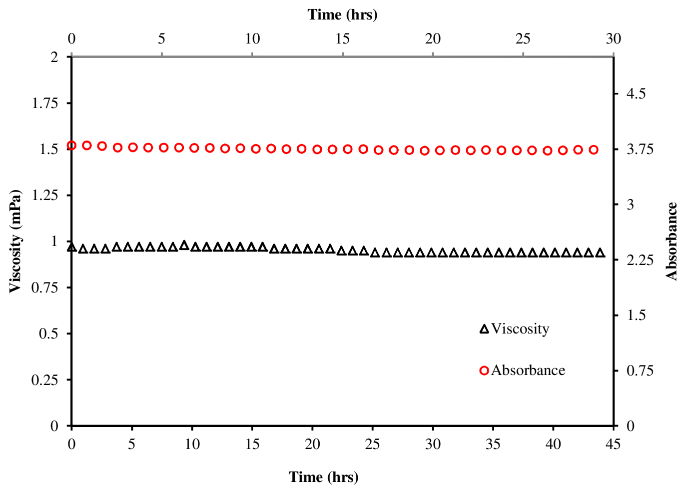

Figure 3 Stability of nanofluid in terms of absorbance and viscosity at constant temperature

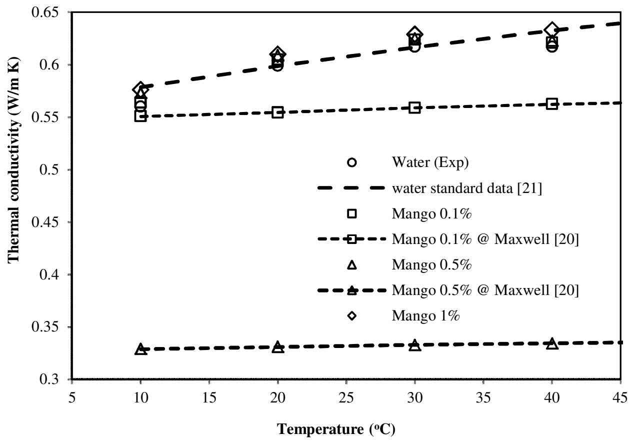

Figure 4 Thermal conductivity of nanofluids

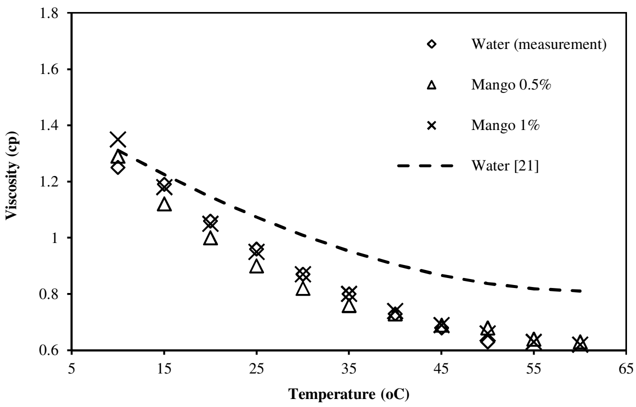

Figure 5 Viscosity variations of nanofluids

CONCLUSION

A new kind of environmentally safe bio nanofluids is prepared and characterised. The thermophysical properties such as viscosity and thermal conductivity are measured and presented. Though the experimental thermal conductivity of the nanofluids shows an enhancement, the theoretical thermal conductivity is deteriorated as the thermal conductivity of the wood is much lower than that of the base fluid. Even though the performance of the nanofluids is not favourable, this study will pave a way for finding new environmentally safe nanofluids with higher performance.

REFERENCES

[1]. Choi SUS., Enhancing thermal conductivity of fluids with nanoparticles, *ASME FED,* Vol. 231, 1995, pp. 99-105.

[2]. Yu W., and Xie H., A review on nanofluids: Preparation, Stability Mechanisms and applications, *Journal of Nanomaterials*, Vol. 2012, Article Id 435873,17 pages

[3]. Ghadimi A., Saidur R., and Metselaar HSC., A review of nanofluid stability properties and characterization in stationary conditions, *International Journal of Heat and Mass Transfer,* Vol. 54, 2011, pp. 4051-4068.

[4]. Aybar HŞ., Sharifpur M., Azizian MR., Mehrabi M., and Meyer JP., A Review of Thermal Conductivity Models of Nanofluids, *Heat Transfer Engineering,* Vol. 36, 13, 2015, pp. 1085-1110.

[5]. Mishra PC., Mukherjee S., Nayak SK., Panda A., A brief review on viscosity of nanofluids, *International nano letters*, Vol. 4, 2014, pp. 109-120.

[6]. Meyer JP., Adio SA., Sharifpur M., and Nwosu PN., The viscosity of nanofluids: a review of the theoretical, empirical, and numerical models, *Heat Transfer Engineering,* Vol. 37, 2016, pp. 387-421.

[7]. Shahsavar A., Salimpour MR., Saghafian M., and Shafii M.B., Effect of magnetic field on thermal conductivity and viscosity of a magnetic nanofluid loaded with carbon nanotubes, *Journal of Mechanical Science and Technology,* Vol. 30 (2), 2016, pp. 809-815.

[8]. Song D., Jing D., Geng J., Ren Y., A modified aggregation based model for the accurate prediction of particle distribution and viscosity in magnetic nanofluids, *Powder Technology,* Vol. 283, 2015, pp. 561–569.

[9]. Song D., Jing D., Luo B., Geng J., and Ren Y., Modeling of anisotropic flow and thermodynamic properties of magnetic nanofluids induced by external magnetic field with varied imposing directions, *Journal of Applied Physics,* Vol. 118, 2015, Paper no. 045101.

[10]. Leong K.Y., Ku Ahmad K.Z., Ong HC., Ghazali MJ., Baharum A., Synthesis and thermal conductivity characteristic of hybrid nanofluids – A Review, *Renewable and Sustainable Energy Reviews*, http://dx.doi.org/10.1016/j.rser.2016.11.068

[11]. Tabet L., Bussy C., Amara N., Setyan A., Grodet A., Rossi MJ., Pairon JC., Boczkowski J., and Lanone S., Adverse effects of industrial multiwalled carbon nanotubes on human pulmonary cells, *Journal of Toxicology and Environmental Health*, Vol. 72(2), Part A, 2009, pp. 60–73

[12]. Korani M., Ghazizadeh E., Korani S., Hami Z., and Mohammadi-Bardbori A., Effects of silver nanoparticles on human health, *European Journal of Nano medicine*, Vol. 7(1), 2015, pp. 51–62.

[13]. Panyala NR., Pena-Mendez EM., Havel J., Silver or silver nanoparticles: a hazardous threat to the environment and human health?, *Journal of Applied Biomedicine*, Vol. 6, 2008, pp. 117-129.

[14]. Chang X., Zhang Y., Tang M., Wang B.,, Health effects of exposure to nano-TiO2: a meta-analysis of experimental studies, *Nanoscale Research Letters,* Vol. 8,2013, Paper no. 51.

[15]. Tucci P., Porta G., Agostini M., Dinsdale D., Iavicoli I., Cain K., Finazzi-Agro A., Melino G., Willis A., Metabolic effects of TiO_2

nanoparticles, a common component of sunscreens and cosmetics, on human keratinocytes, *Cell Death and Disease,* Vol. 4, 2013, Paper no. 549

[16]. Qi W., Bi J., Zhang X., Wang J., Wang J., Liu P., Zhan Li, Wu W., Damaging Effects of Multi-walled Carbon Nanotubes on Pregnant Mice with Different Pregnancy Times, *www.nature.com,* scientific reports, Vol. 4, DOI: 10.1038/srep04352

[17]. Gosteva I., Morgalev Y., Morgaleva T., Morgalev S., Effect of Al_2O_3 and TiO_2 nanoparticles on aquatic organisms, IOP Conf. Series: *Materials Science and Engineering,* Vol. 98, 2015, Paper no. 012007

[18]. Exbrayat JM., Moudilou EN., Lapied E., Harmful Effects of Nanoparticles on Animals, *Journal of Nanotechnology,* Vol. 2015, Article ID 861092

[19]. Tlili A., Cornut J., Behra R., Gil-Allué C., Gessner MO., Harmful effects of silver nanoparticles on a complex detrital model system, *Nanotoxicology,* Vol.10(6), 2016, pp. 728-735

[20]. Nadooshan AA., An experimental correlation approach for predicting thermal conductivity of water-EG based nanofluids of zinc oxide, *Physica E: Low-dimensional Systems and Nanostructures*, Vol. 87, 2017, pp. 15-19.

[21]. Ramires MLV., Nieto de Castro CA., Nagasaga Y., Nagashima A., Assael M.J., and Wakeham W.A., Standard reference data for thermal conductivity of water, *American Institute of Physics and American Chemical Society*, Technology Report 1995, pp. 1377-1381.

[22]. Huminic A., Huminic G., Fleaca C., Dumitrache F., Morjan I., Thermal conductivity, viscosity and surface tension of nanofluids based on FeC nanoparticles, *Powder Technology*, Vol. 284,pp. 78-84.