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Thermal conductivity of carbon nanofiber in EG-DI based nanofluids

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ABSTRACT – This paper was aimed at formulating a stable nanofluid from CNF HHT24 in a base fluid consisting of deionized water (DI) and ethylene glycol (EG) with the presence of polyvinylpyrrolidone (PVP) as dispersing agent. The experiment was conducted by setting the variable weight percentage of CNF from 0.1wt% to 1.0wt%, with the base fluid ratio being 70:30 (DI:EG) weight percent. Then, the thermal conductivity was investigated at three different temperatures which are at 6ºC, 25ºC and 40ºC. The highest thermal conductivity was gained at 1.0wt% at temperature 40°C with thermal conductivity value of 0.499 W/m.K. Meanwhile, the highest percentage enhancement in thermal conductivity were obtained by 1.0wt% at 40ºC with 6.62%. Overall, nanofluids proved to have a greater potential to be commercialized as conventional heat transfer fluids due to its good thermal properties.

1. INTRODUCTION

Highly thermally conductive particles such as carbon nanotubes, metal and metal oxides which possess high thermal conductivity have concerned researchers to investigate the performance of existing heat transfer system by adding these materials into a heat transfer fluid to improve the thermal conductivity [1]. Scientists at Argonne National Laboratory was the first one who invented nanofluids by the dilution of liquid particle mixtures which improves the thermal conductivity values of about 20-150% higher than the conventional heat transfer fluids [2]. Numerous studies had been reported in literature regarding the enhancement of thermal conductivity of nanofluids which was prepared by mixing the nanocarbon with conventional base fluids such as water and ethylene glycol. However, only a few studies regarding the addition of carbon nanofiber into a base fluid have been reported. The amazing thermal capability of nanofluid have make these fluids potentially to be used as superior medium for a heat transfer media. Thus, the focus of this study is to formulate a stable nanofluids produced from the mixture of carbon nanofiber (CNF HHT24), base fluid (DI and EG) and dispersing agent.

Then, the thermal conductivity of formulated nanofluid with varying volume concentrations ranging from 0.1wt% to 1.0wt% are studied.

2. METHODOLOGY

2.1 Nanofluids preparation

The nanofiber used in this research were Pyrograf III Carbon Nanofiber HHT24. The polyvinylpyrrolidone (PVP) from Sigma-Aldrich Co. was chosen as a dispersing agent. The nanofluids were synthesized with varying volume concentrations ranging from 0.1wt% to 1.0wt% with the base fluid ratio of 70:30 (DI:EG) weight percent. These mixtures are then homogenized using the mechanical homogenizer for five minutes by using a Digital Homogenizer LHG-15 at 10000 rpm rotational speed. The mixture then was ensured to be dispersed uniformly using ultrasonic at 25ºC for 5 minutes at 37 kHz frequency. The nanofluid dispersion and stability were then observed by using Stability Test Rig (STR) as to make sure the nanofluid were well dispersed.

2.2 Thermal conductivity measurement

All the samples which had been stabilised then were tested for their thermal conductivity. A KD2-Pro Thermal Properties Analyser (Decagon Devices, Inc.) was used to measure the thermal conductivity at three different temperatures of 6°C, 25°C and 40°C. These three temperature was selected to study the temperature effect to the thermal conductivity of nanofluids. A single-needle KS-1 sensor, with a length of 60 mm and a diameter of 1.3 mm, was used to measure the thermal conductivity.

3. RESULTS AND DISCUSSION

The thermal conductivity of nanofluid for volume concentration ranging from 0.1wt% to 1.0wt% with respect to temperature is shown in Figure 1. The results also include the standard thermal conductivity data for mixture of 70:30 (DI and EG). The graph from Figure 1 shows that most of the nanofluid samples exhibited an increasing thermal conductivity higher than the standard suspension.

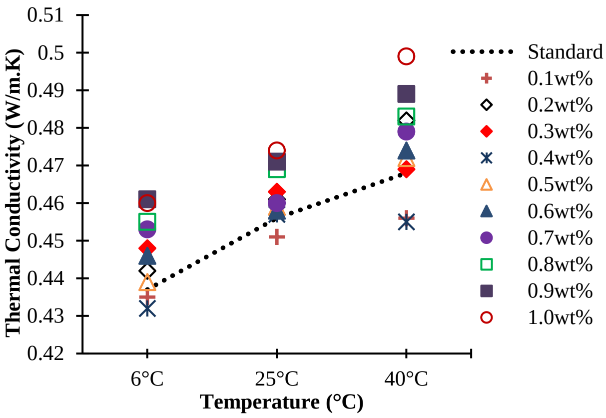

Figure 1 Thermal conductivity of nanofluids in various concentration.

The results show variability for all the temperatures, but it could be seen that the rise in thermal conductivity varied with an increment in nanofluid concentration. The highest thermal conductivity was obtained at temperature 40°C for 1.0wt% with thermal conductivity value of 0.499 W/m.K. However, there were two samples with conductivities that were exceptionally lower than the standard, and these were the 0.1wt% and 0.4wt% samples. The possible reason was because ethylene glycol had a lower thermal conductivity compared to deionized water. Thus, when these two fluids were mixed together, it led to a decrease in thermal conductivity. The enhancement analysis was done to observe the trend, which was compared to the standard fluid. The enhancement percentages of the nanofluids are shown in Table 1.

Table 1 Enhancement percentage of nanofluids.

Volume Concentration (wt%)	Percentage of Enhancement (%) at Temperature (ºC) 6	25	40
0.1	-0.45	-1.09	-2.56
0.2	1.14	1.10	2.99
0.3	2.52	1.53	0.21
0.4	-1.14	0.22	-2.78
0.5	0.46	0.65	0.85
0.6	2.06	0.44	1.28
0.7	3.66	0.88	2.35
0.8	4.12	2.85	3.20
0.9	5.49	3.29	4.48
1.0	5.26	3.94	6.62

At 6°C, nanofluid sample with 0.9wt% had the highest enhancement in thermal conductivity with 5.49% percent enhancement. Meanwhile, at 25°C and 40°C, the highest enhancement in thermal conductivity was represented by 1.0wt% with 3.94% and 6.62% respectively. The negative value indicated that there was no improvement in the thermal conductivity, which means that the thermal conductivity was lower than the standard suspension. It can be clearly seen from Table 1 that there was no enhancement for the 0.1wt% and 0.4wt% samples. Various reviews and studies covering factor which effect the thermal conductivity of nanofluids have been reported. Gao et al. has revealed the increase in cluster size of nanoparticles has significant impact on the enhancement of thermal conductivity [3]. Some previous studies also reported a linear relation between increasing of thermal conductivity with increasing of particle volume fraction. However, there are also some studies reported a non-linear behavior in thermal conductivity. The possible reason was due to the increase in nanofluids concentration which cause the viscosity of base fluid to increase and consequently cause a reduction in thermal conductivity of nanofluids [4]. The viscosity of the base fluid affects the Brownian motion of nanoparticles and the thermal conductivity of the nanofluid [5-6].

4. CONCLUSION

These findings suggest that the addition of CNF HHT24 nanocarbon into a mixture of ethylene glycol and deionized water as base fluid has proved to exhibit enhancements in their thermal conductivity value. The highest thermal conductivity was gained at 1.0wt% volume concentration at 40ºC with thermal conductivity value of 0.499 W/m.K. Overall, nanofluids proved to have a wide prospect to be commercialized as conventional heat transfer fluids due to its good thermal capability.

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REFERENCES

[1] M.A. Sabiha, R.M. Mostafizur, R. Saidur and S. Mekhilef, "Experimental investigation on thermo physical properties of single walled carbon nanotube nanofluids," *Int. J. Heat Mass Transfer,* vol. 93, pp. 862-871, 2016.

[2] A. Nasiri, M. Shariaty-Niasar, A. Rashidi and R. Khodafarin, "Effect of CNT structures on thermal conductivity and stability of nanofluid," *Int. J. Heat Mass Transfer,* vol. 55, no. 5, pp. 1529-1535, 2012.

[3] J. Gao, R. Zheng, H. Ohtani, D. Zhu and G. Chen, "Experimental investigation of heat conduction mechanisms in nanofluids: clue on clustering," *Nano Lett.,* vol. 9, no. 12, pp. 4128-4132, 2009.

[4] T.H. Tsai, L.S. Kuo, P.H. Chen and C.T. Yang, "Effect of viscosity of base fluid on thermal conductivity of nanofluids." *Appl. Phys. Lett,* vol. 93, no. 23, pp. 1-3, 2008.

[5] S.N. Syed Idrus, N.S. Zaini, I.S. Mohamad, N. Abdullah and M. H. Mohd Hussin, "Comparison of thermal conductivity for HHT-24 CNF based nanofluid using deionized water and ethylene glycol," *Jurnal Teknologi,* vol. 77, no. 21, pp. 85-89, 2015.

[6] I.S. Mohamad, S.B.A. Hamid, W.M. Chin, K.H. Yau and A. Samsuri, "Nanofluid-based nanocarbons: an investigation of thermal conductivity performance," *Journal of Mechanical Engineering and Technology,* vol. 3, no. 1, pp 79-87, 2011.