2012 International Conference on Environment, Chemistry and Biology
IPCBEE vol.49 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2012. V49. 24

Comparative Study on Thermal Conductivity Enhancement in Water Added MWCNTs

Sung Seek Park and Nam Jin Kim+

Department of Nuclear & Energy Engineering, Jeju National University, Jeju, 690-756, Korea

Abstract. The carbon particles with metal lattice or graphite structures generally exhibit thermal conductivities that are hundreds of times greater than pure fluids. Especially due to their outstanding electric and thermal conductivities, carbon nanotubes have become an important entity in the scientific field. So, in this work Experiments were carried out to compare the thermal conductivity and viscosity in distilled water with two types of MWCNTs. nanofluids were made by ultrasonic dispersing carbon nanotubes in the distilled water. The thermal conductivity and viscosity of nanofluids were measured by using transient hot-wire method and rotational digital viscometer, respectively. The result that it is important to disperse oxidized MWCNTs if a stable solution of MWCNTs is to be achieved for the production of a reliable nanofluid, and thermal conductivity of oxidized CM-100 with more long length is higher than that of oxidized CM-95.

Keywords: Thermal conductivity, Viscosity, MWCNTs, Transient hot-wire method, Volumetric ratio.

1. Introduction

Heat transfer is one of the most important processes in many industrial and consumer products. The inherently poor thermal conductivity of conventional fluids puts a fundamental limit on heat transfer. Therefore, for more than a century since Maxwell[1], scientists and engineers have made great efforts to break this fundamental limit by dispersing micrometer- or nano-sized particles in liquids. The nanofluid terminology, which describes fluid combined nanoparticles, was introduced by Choi of the Argonne National Laboratory in the U.S Department of Energy[2]. The carbon particles with metal lattice or graphite structures generally exhibit thermal conductivities that are hundreds of times greater than pure fluids. Especially due to their outstanding electric and thermal conductivities, carbon nanotubes (CNTs) have become an important entity in the scientific field [3]. So, in this work, the production of nanofluids is considered by the chemical reformation process where hydroxyl radicals are combined with MWCNTs after oxidation treatment. Experiments are carried out to elicit the most proper mixture ratio of nanoparticles by measuring thermal conductivity via transient hot-wire method and viscosity using a rotary-type digital viscometer in water for the heat transfer enhancement of the heat pipe in solar vacuum tube.

2. Experimental Equipment and Procedure

2.1. Materials

The CNTs were made by chemical steam deposition with 95% purity and can be classed as MWCNTs. These were purchased from Hanwha Nanotech Corporation and their properties are given in Table 1. MWCNTs were dissolved in 50 ㎖ of distilled water with variable volumetric ratios of 0.001 ∼ 0.02%. It took two hours to prepare the nanofluid after processing the solution as the dispersion of nanoparticles was completed by an ultrasonic dispersion unit.

+ Corresponding author. Tel.: + 82-064-743-3643; fax: +82-064-757-9276.
E-mail address: jnkim@jejunu.ac.kr.

Table 1 Properties of MWCNTs

Properties	CM-95	CM-100
Diameter(㎚)	10～15	10～15
Length(㎛)	10～20	～200
Purity (wt.%)	95	95
Bulk Density(g/cm^3)	0.1	0.05
Surface Area(m^2/g)	200	225

2.2. Thermal Conductivity Measurement

A transient hot-wire method was used to measure the fluid thermal conduction. This method does not suffer from any problem due to the effect of convection currents and facilitates the measurement by allowing a simple electric circuit to handle its functional algorithm. The thermal conductivity measuring equipment employing a transient hot-wire method consists of a Wheatstone bridge to detect the change in thermal wires and a data logger connected to a computer. The Wheatstone bridge here assures the precise measurement of resistance, which consists of four resistors symmetrically positioned. An ammeter is used to determine the voltage-drop in each resistor when a voltage is applied causing current to flow. The thermal conductivity is then determined by converting the measured voltage to the corresponding resistance and temperature values. That is, the 10 kΩ variable resistor is adjusted until the applied voltage on the ammeter vanishes and subsequently 15V is applied to the circuit to generate heat by the platinum resistor wire. The heat generated then changes its surface temperature, which increases the resistance of the platinum resistor wire. A data logger constantly measures and records the data by constantly monitoring these variations. There is a linear relationship between the electrical resistance and temperature of the platinum resistor wire, which has been well introduced in the previous studies [4]. Especially, during the unsteady period, the temperature given by this relationship exhibits a linear correlation with time on a log scale. The following equation has been derived from such relationship in link with temperature and time measurements. It allows the resolution of thermal conductivity for nanofluids without undue difficulties.

$$K = \frac{q}{4\pi\left(T_2 - T_1\right)} \ln\left(\frac{t_2}{t_1}\right)$$

Here, K is the fluid thermal conductivity and T_1 and T_2 are the measured platinum wire temperatures at time t_1 and t_2, respectively.

2.3. Nanofluid Viscosity Measurement

To measure the viscosity of nanofluids, a rotation-type viscometer was employed, which uses a weight-driven rotating paddle to sense the viscosity of fluid spinning at a constant angular velocity. The viscometer allows the adjustment of rotational speed in the range of 0~200 rpm, and its major components include a weight-driven rotating paddle set, a constant temperature bath and a computer for data management and storage. For comparative data analyses, fluid samples are kept at 25℃, when measuring the viscosity. Also, as the present analysis involves low viscosity measurements, a weight suitably designed for low viscosity measurements (LV-64) was used with a maximum rotational speed of 200 rpm.

3. Experimental Results

3.1. Carbon Nanotubes Dispersion

Fig. 1 shows the carbon nanofluids produced by applying various dispersion methods with 0.001 vol% MWCNTs. As clearly shown in this figure, the MWCNTs and oxidized MWCNTs were distributed more or less evenly in the distilled water immediately after the dispersion process. 24 hours later, however, the one prepared only with MWCNTs shows a mass of sunken MWCNTs at the bottom. This indicates that the dispersion of MWCNTs cannot be sustained for a long time when prepared only by mechanical agitation. It is important to disperse oxidized MWCNTs if a stable solution of MWCNTs is to be achieved for the production of a reliable nanofluid.

(a) 0 hour (b) 24 hours

Fig. 1: Photographs of after sonicator dispersion.

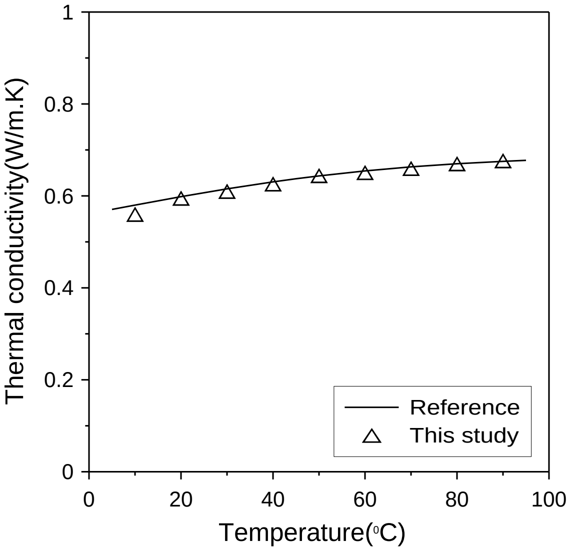


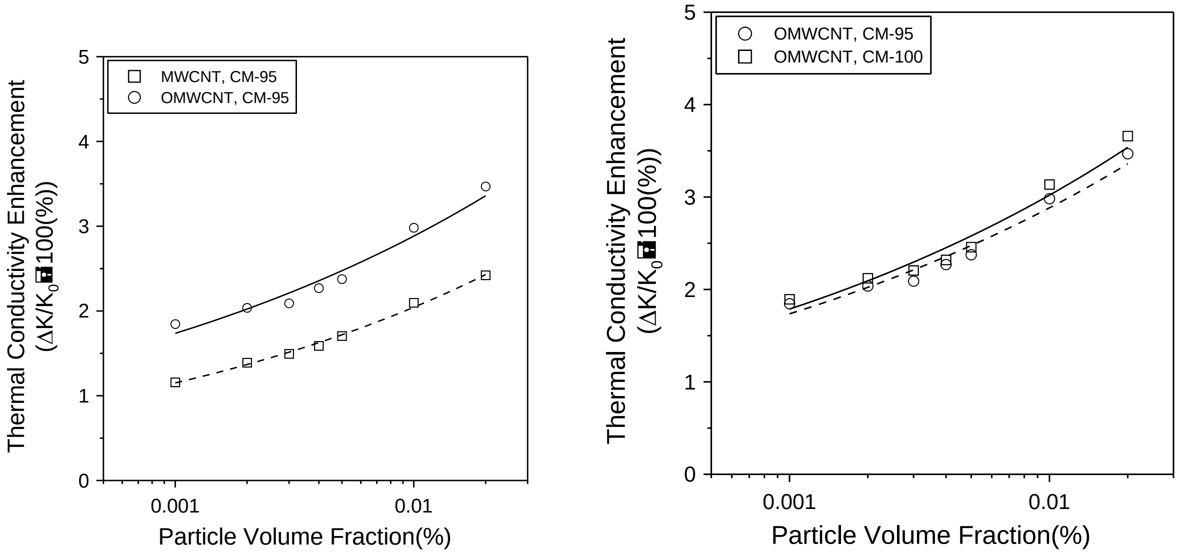
Fig. 2: Measured thermal conductivity of the base fluid and reference values.

3.2. Thermal Conductivity Measurement

Fig. 2 graphically compares the thermal conductivity of distilled water where its measured values in the present study are plotted against a reference curve from a relevant resource handbook [5]. It shows a very good agreement where the measured and reference values lie within a 1% margin of error. This verifies the validity of our approach in preparing the base fluid (distilled water) for nanofluids. Fig. 3(a) compares the thermal conductivity of two nanofluids where one is prepared by adding MWCNTs and the other by dispersing oxidized MWCNTs in distilled water. As shown, the one with dispersed oxidized MWCNTs exhibited 46% higher performance than that of MWCNTs. Therefore, to increase the thermal conductivity of MWCNTs, it is necessary to oxidize their surface of MWCNTs. Fig. 3(b) shows the comparison of the thermal conductivity of oxidized CM-95 and CM-100 nanofluids. As shown in the figure, the thermal conductivity of oxidized CM-100 is 4% higher than that of oxidized CM-95. This means that the thermal conductivity of MWCNTs with more long length is high at the same diameter.

3.3. Viscosity Measurement

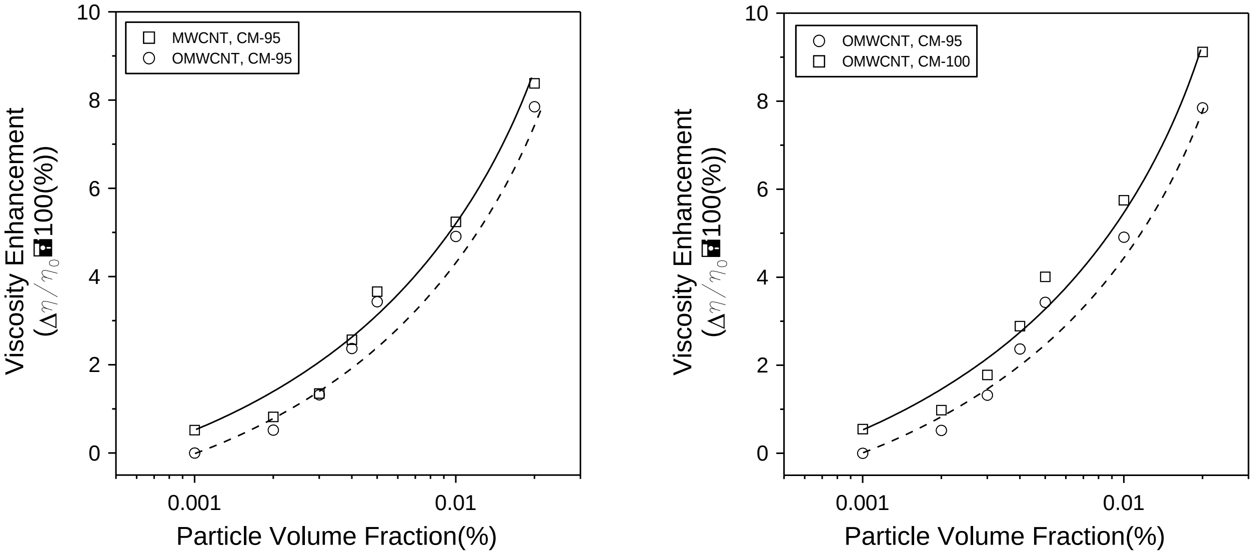
Fig. 4(a) shows the comparison of the viscosity of CM-95 and oxidized CM-95. As shown in the figure, the viscosity of oxidized CM-95 is about 11% lower. This means oxidization makes the viscosity decreases. Fig. 4(b) compares the viscosity of oxidized CM-95 and CM-100. In the figure, CM-100 increases about 23% in viscosity because of the longer length of CM-100 than that of CM-95



(a) CM 95

(b) CM-95 and CM-100

Fig. 3: Comparison of the thermal conductivity of MWCNT and OMWCNT



(a) CM 95

(b) CM-95 and CM-100

Fig. 4: Comparison of the viscosity of MWCNT and OMWCNT

4. Summaries

Experiments were carried out to compare the thermal conductivity and viscosity in distilled water with two types of MWCNTs. The result that it is important to disperse oxidized MWCNTs if a stable solution of MWCNTs is to be achieved for the production of a reliable nanofluid, and thermal conductivity of oxidized CM-100 with more long length is higher than that of oxidized CM-95.

5. Acknowledgements

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (No. 2012029406)

6. References

[1] J. C., Maxwell, *A Treatise on Electricity and Magnetism*, 2nd ed., Vol. 1, Clarendon Press, Oxford, UK, 1881.

[2] Choi, S.U.S., Enhancing thermal conductivity of fluids with nanoparticles, Development and Applications of Non-Newtonian Flows, ed. by Singer, D.A. and Wang, H.P., *FFD-Vol.231/MD-Vol. 66, ASME New York,* 1995, 474-

480.

[3] S. U. S. Choi, Z. G. Zhang, W. Yu, F. E. Lockwood, E. A. Grulke, Anomalous thermal conductivity enhancement in nanotube suspensions, *Appl. Phys. Lett.* 2001, 79 (14): 2252-2254.

[4] J. P. Bently, Temperature sensor charcteristics and measurement system design, *Journal of Physics E: scientific Instruments.* 1984, 17: 430-435.

[5] D. R. Lide, Ed., *CRC Handbook of Chemistry and Physics*, CRC Press, 89th ed., 2008.