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A Comparative Study on the Characteristics of Carbon Nanotubes and Graphene Nanofluids for Efficiency Enhancement of Nuclear Power Plant Heat Exchanger

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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, 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 [1]. 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 and graphene have become an important entity in the scientific field.

Therefore, in this work, experiments are carried out to measure the thermal conductivity via transient hot-wire method and the viscosity using a rotary-type digital viscometer of carbon nanotubes and graphene.

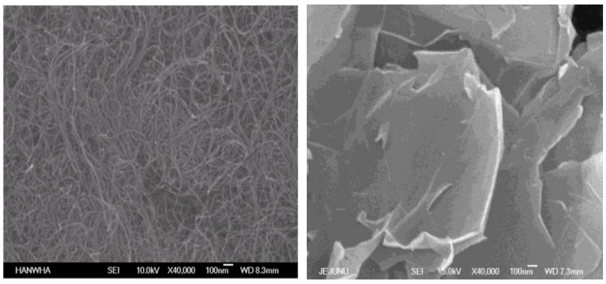
2. Experimental

2.1 Materials

The carbon nanotubes and graphene were used in this study, and these were purchased from Hanwha Nanotech Corporation whose properties are given in Table 1. To prepare the base fluid in making nanofluids, tap water has been processed via an automatic water distiller (ADA-04). Fig. 1 shows 40,000 magnified image of MWCNTs and grapheme by a scanning electron microscopy (SEM).

Table 1: Properties of MWCNTs and Graphene

Properties	MWCNTs	Graphene
Diameter(㎚)	10-15	15
Length(㎛)	10-20	-
Thickness(㎚)	-	6-8
Purity (wt.%)	95	>99.5
Bulk Density(g/cm^3)	0.1	0.03-0.1
True density(g//cm^3)	1.8	2.2
Thermal conductivity(W/m·K)	3000	3000
Surface Area(m^2/g)	200	120-150



(a) MWCNT (b) Graphene
Fig. 1. SEM image(×40,000)

2.2 Apparatus and methods

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 (designed on the basis of some basic knowledge in electricity) 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 as shown in Fig. 2. 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 15 V 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 (in voltage). 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 [2]. Especially, during the unsteady (transient) 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.

$$k = \frac{q}{4\pi(T_2 - T_1)} ln\left(\frac{t_2}{t_1}\right) \qquad (1)$$

To measure the viscosity of nanofluids, a rotation-type viscometer (Brookfield Engineering Lab., digital viscometer DV II+pro) 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 (TC-502) 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 and discussion

3.1 Thermal conductiviy

Fig. 2 is a graphical representation of the measured thermal conductivity when carbon nanotubes and graphene was added to the solution at volumetric ratios of 0.0005-0.01%. As shown in the figure, the thermal conductivity tends to increase along with the particle's volumetric ratio, and the thermal conductivity of graphene is 2 times higher than that of MWCNTs.

3.2 Viscosity

Fig. 3 shows the variation in viscosity ratios as a function of particle volume fraction of MWCNTs and graphene up to 0.01 % at at 25℃. As shown in the figure, the viscosity of grapheme is about 3 times higher than that of graphene because of the plate shape.

4. Conclusions

Experiments were carried out to elicit the most proper mixture ratio of MWCNTs and grapheme by measuring thermal conductivity via transient hot-wire method and viscosity using a rotary-type digital viscometer. The results of this experiment were that the thermal conductivity increased along with the volumetric fraction, and MWCNTs is higher than that of graphene. However, the viscosity of grapheme is much higher than that of graphene because of the plate shape.

Acknowledgement

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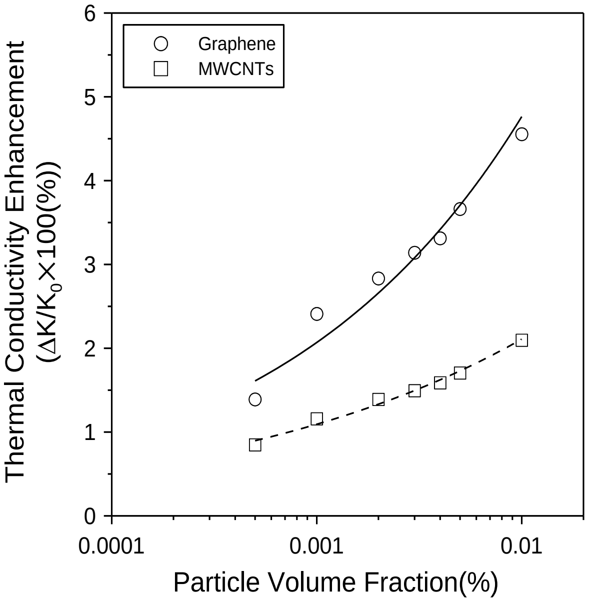

Fig. 2. Comparison of the thermal conductivity enhancement ratios as a function of particle volume fraction at 25℃

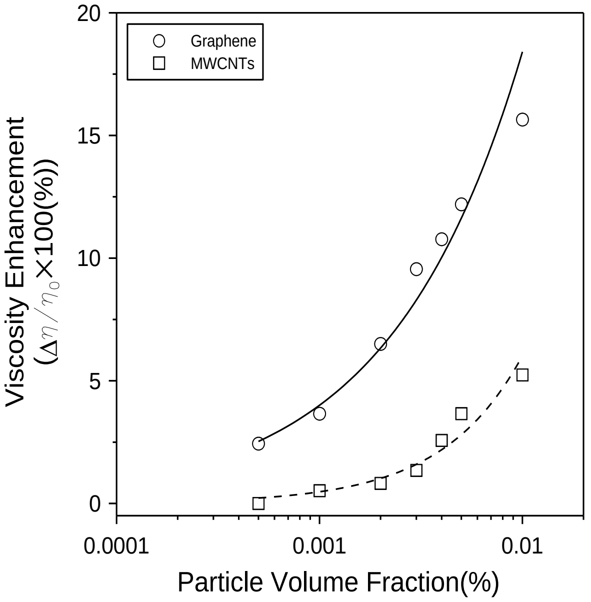

Fig. 3. Comparison of the viscosity enhancement ratios as a function of particle volume fraction at 25℃

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