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Measurement of the Thermal Conductivity of Nano-fluid for the advanced heat exchanger

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1. Introduction

The enhancement of heat transfer has been widely investigated to provide an effective way to cool down the modern electronic devices. Among the methods, Choi discovered a large amount of increase of thermal conductivity when nano sized particles were suspended in the fluid. It was first introduced by Masuda as a potential heat transfer enhancement media and since then, many researchers have investigated the nanofluids phenomena. Many researchers reported in substantially increasing the thermal conductivity of fluids by adding small amounts of suspended metallic oxide nanoparticles of Cu, CuO, Al_2O_3 and carbon nano-tube. Masuda reported that the use Al_2O_3 particles of 13 nm at 4.3% volume fraction increased the thermal conductivity of water by 30%. For carbon nano-tube nanofluids shows even greater enhancement. Xie et al. measured the thermal conductivity of carbon nanotube suspended in organic liquid and water with the enhancement of 10-20%. Recent studies have shown that inserting just 1% concentration of nano-particles sometimes increases about maximum 40% of thermal conductivity. However, there is still few experiments done for TiO_2 nanoparticles. Murshed found that the enhancement of thermal conductivity shows about 30% with 15nm in diameter with maximum 5% volume fraction and about 40% enhancement is observed using 15nmD x 40nm rod-shape nanoparticles of TiO_2. The present experimental shows that a 20% maximum of enhancement in thermal conductivity using TiO_2 of 10nm for 3% volume fraction. Theses results are compared with previous research with theoretical models. As the first step of the heat transfer of nano fluid, the theories related to the nanofluids investigations have been discussed to understand not only the mechanism of thermal conductivity measurement, but also to understand the nanofluid behavior. Colloidal stability is the key to the nanofluid considered to prevent the agglomeration. Through the results, we will discuss the importance of this matter. The measurement of the thermal conductivity of the nano fluid is investigated here by developing the sensor body and circuit.

2. Sensor Development

To obtain real representation on the variation of temperature a single wire probe is needed sensor part consists with a thin wire of Tantalum, diameter of 0.025mm.and length of 70mm. Tantalum wire are strong and have a high temperature coefficient of resistance, (β=3.9092x10^{-3} K^{-1}) and Tantalum oxide is a great insulator and excellent dielectric material which can be easily made through an anodization process annexed with citric acid of 0.01%wt. The constant current through the hot wire invade in the medium cause error on the data due to the electrical conduction and polarization. An anodized layer of tantalum oxide on the tantalum hot wire provided the electrical insulation during the measurements. The body of hot wire sensor is limited to cylindrical shapes as shown in Figure 1. The sensor body is made of PTFE material to tolerate in acidic liquid. Nanofluids measured here has acidity of about pH=3. The tested volume for each experiment is taken in the sample container with volume of 40 ml. Based on the theoretical basis, the dimension of the container is large enough to consider the fluid inside it as infinite medium from the hot wire.

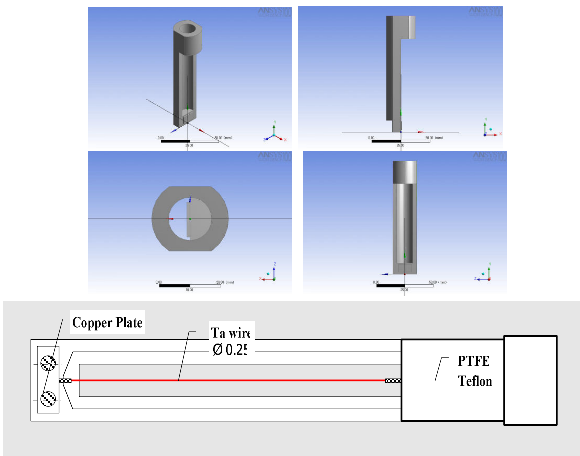

Fig. 1. The schematic of Tantalum hot wire sensor

The hot wire is excited by the constant current source to determine the temperature of the sensor. which depicts the electronics of the present method. As shown in Figure 2, the Wheatstone bridge circuit, organized as dynamic unbalanced, used by setting the adjustable resistor to the resistance of the hot wire to measure the sensitive change of the resistance during the operation. A single signal from constant current source is conveyed into the Signal conditioner circuit and amplified the output signal of voltage difference. In the Signal conditioner, Unit differential amplifier (INA 105, 0.01% error) is used to keep the error voltage zero. The difference voltage then amplified with the gain of 100 throughout the High Speed Amplifier (AD817). Due to the sensitivity of noise could be susceptible to stray electrical interference in the main input pulse which can cause false time measurements. In order to obviate this difficulty, R-C filter is used in the present circuit to obtain resistance difference from hot wire, considerably attenuate main frequency signals and eliminate the noise. The amount of constant current adjusted to less than 100mA in order to obtain the non-linear signal of voltage difference. The mathematical formulation for temperature rise of the hot wire is established

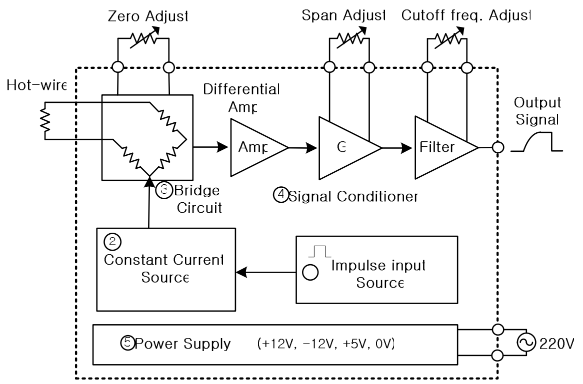

Fig. 2. The Block diagram of experiment circuit.

3. Results

TiO2 nanoparticles of 10nm is dispersed in deionized water with different volume fraction has been tested to measure the thermal conductivity. Figure 4 shows the variation in temperature of wire within in 0.05 second as a function of time. Data are plotted and normalized to the conductivity of water. It shows that as the slope decreases as the volume fraction of nanofluids increases which result in enhancement in thermal conductivity.

Most of theories developed to compute the thermal conductivity of solid particle suspensions. These are based on the morphology and thermal conductivity of the particles, and volume fraction of solid and liquid. These models already been verified with large particles suspensions at low concentrations, however non of these can predict the thermal conductivity of nano sized particles suspended in the fluid. As shown in Figure 5, the model of Hamilton and Crosser failed to determined the effective thermal conductivity of nanofluids.

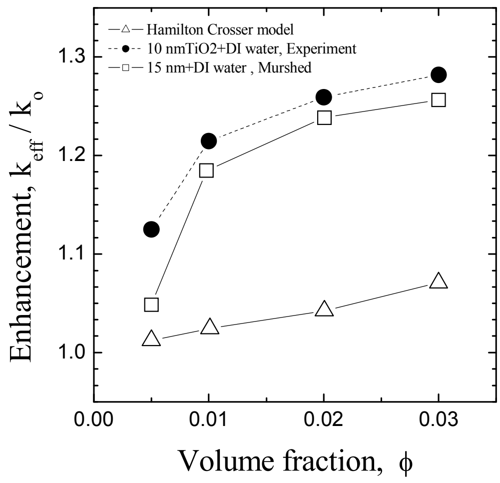

Fig. 3. Comparison between experimental and theoretically determined thermal conductivity of TiO_2(10nm)/DI water with Oleic acid(0.02vol%).

4. Conclusions

A sensor and electronics to measure the thermal conductivity of the nano fluid is developed based on the hot wire method. It was found that the present method could be applicable to the study of development of compact and efficient heat exchanger for the nuclear industry.

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