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Thermal Conductivity Measurement and Heat Transfer Investigation of TiO_2 and Al_2O_3 Nanofluids

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1. Introduction

Pool boiling heat-transfer often occurred in the main part of nuclear power plant with rapid increasing of heat flux according to increasing of over-heated wall. After reaching at the critical point, rapid decreasing of heat flux occurs. The boundary region where the heat flux is increased and decreasing with increasing of wall temperature, is called critical heat flux condition and passing this point, we can see the transition pool boiling region in where the over-heated wall increases and heat-transfer decreases. In this case the temperature of heat source increases rapidly and it can cause serious danger.
Nano-fluid has a capability, increasing the heat transfer efficiency greatly by the mean of dispersing nano-size metal particles in fluid. In this study the thermal conductivity of nanofluids is measured and the heat transfer investigation is done in the nucleate region, using TiO2 and Al2O3 nanofluids.

The enhancement of heat transfer has been widely investigated to provide effective ways to cool down the modern electronic devices. Among the methods, Choi[1] discovered a large amount of increase of thermal conductivity when nano sized particles were suspended in base fluid such as deionized water and ethylene glycol. Many researchers reported in substantially increasing the thermal conductivity of fluids by adding small amounts of suspended metallic oxide nano particles of Cu, CuO, Al_2O_3 and carbon nano-tube. It was first introduced by Masuda[2] as a potential heat transfer enhancement media and since then, many researchers have investigated the nanofluids phenomena. However, there are still few thermal conductivity enhancement experiments for TiO_2 nanofluids. Murshed[3] have found that the TiO_2 nanofluids increases about 30% enhancement with 15nm in diameter with the maximum of 5% volume fraction, and 40% enhancement is observed using D15nm x 40nm rod-shape TiO_2 nanoparticles. In the present paper, the measurement of thermal conductivity of various sizes of TiO_2 nanoparticles immersed in deionized water is done.

2. Thermal Conductivity Measurement

2.1. Measurement Sensor and Circuit.

The hot wire system is designed in accordance with the traditional constant temperature principle with Wheatstone bridge, amplifier and output signal conditioner. The transient hot wire method works by measuring the temperature time response of the wire to the electrical impulse. To obtain real representation on the variation of temperature, a single wire sensor is needed in sensor part consists with a diameter of 0.025mm and length of 70mm Tantalum wire (Temperature coefficient of resistance, β=3.9092x10-3 K-1).

2.2. Nanofluid Preparation

In present research, nanoparticles of 5nm, 10nm and 35nm of TiO_2, and 35nm size of Al_2O_3 are prepared in 0.35, 0.5, 1.0, 2.0, and 3.0 vol% for the thermal conductivity measurements. Sample preparation is done with ultrasonification and magnetic stirring using a high-speed homogenizer (Ultra-Turrax T25, IKA) to overcome the agglomeration of nanoparticles. A considerable preliminary effort was made to investigate the stability of TiO_2 and Al_2O_3 nanofluids of different solids concentrations under various pH conditions as shown in Figure 1.

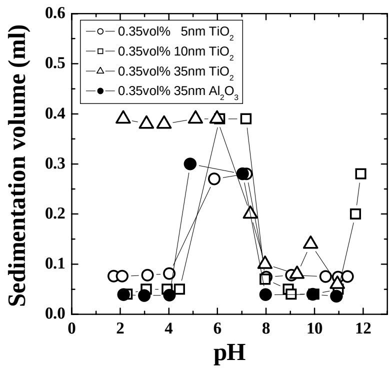

Figure 1. Stability investigation of 0.35 vol% TiO_2 and 0.35vol% of Al_2O_3nanoparticles immersed in deionized water.

As a result, most of TiO_2 and Al_2O_3 nanoparticles is stabilized in the range of pH 8 to 11. The main objective of this is to create repulsive force to counteract the attraction of the particle surfaces. This investigation could visualize the real physics in nanofluids and important issues to avoid the coagulation and sedimentation of the fluid.

2.3. Thermal Conductivity Enhancement of Nanofluids

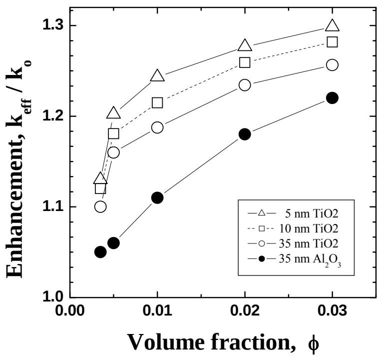

Figure 2. The thermal conductivity enhancement of TiO_2 and Al_2O_3 nanofluids.

The enhancement of thermal conductivity of TiO_2 and Al_2O_3 nanofluids is verified using the transient hot wire sensor and the maximum 28% enhancement of TiO_2 nanofluids at 3.0vol%. For Al_2O_3 nanofluids, the maximum of 21% thermal conductivity enhancement is observed at 3.0 vol%.

3. Subcooled Pool boiling Experiment

3.1. Experiment Facility

To investigate the nanofluids subcooled boiling experiment in nucleate region, 0.35vol% of 10nm TiO_2 is used and experiment facility is designed as shown in Figure 3. There are three parts divided in the experiment facility, the first part is a main container with 1kW heater is fixed to maintain the fluid temperature we want to adjust. Second part is consists with a condenser to resupply vaporized water during the experiment.

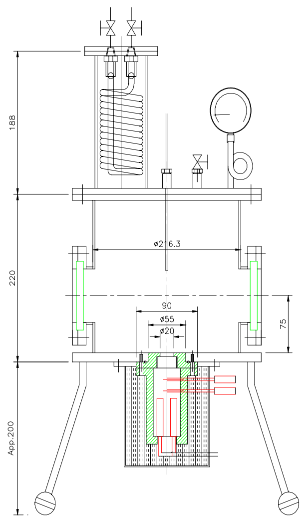

Figure 3. Subcooled pool boiling Experiment Facility

Third part of the facility is consists of three 300Watt heaters fixed in a copper block. Diameter of 20 mm copper surface is exposed on main container where heat transfer occurs through the nanofluids. To investigate the heat transfer occurrence, heat flux is measured with three K-type thermocouples inserted at 25mm, 40mm, and 55mm from the copper block surface. The subcooled boiling is done at temperature of 45°C.

3.1. Subcooled Boiling of TiO_2 Nanofluid

Figure 4. shows the heat transfer coefficient thermocouples inserted at 25mm, 40mm, and 55mm from the copper block surface. The subcooled boiling is done at temperature of 45°C. As many of researchers have said that the heat transfer enhancement is decreased in use of nanoparticles in the base fluids. Also, in the present experiment, the heat transfer coefficient of pure water on the surface of copper block is coated with 10nm TiO_2 is investigated. As a result, the poor heat transfer is shown than water on the clean surface of copper block.

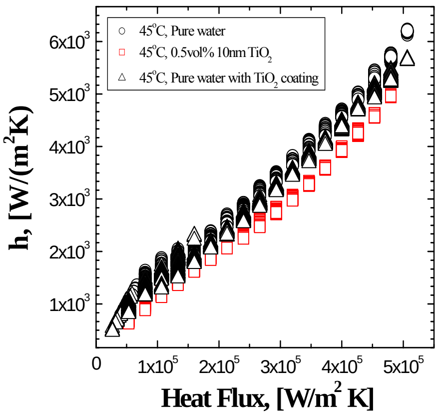

Figure 4. Variation of Heat transfer coefficient of TiO_2 nanofluids compared with water.

6. Summary and Conclusions

In present paper, the maximum 30%, and 21% of thermal conductivity enhancement of TiO_2 and Al_2O_3 nanofluids is obtained. Heat transfer investigation of both nanofluids is done for the further research for the critical heat flux condition in boiling using nano-fluid.

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