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The cooling performance of SiC/water nanofluid during reflood heat transfer in a long vertical tube

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1. Introduction

Many researchers have been trying to create new kinds of heat transfer fluids in order to enhance the heat transfer performance of the base fluids. Nanofluids as new kinds of heat transfer fluids are a new class of nanotechnology-based heat transfer fluids engineered by dispersing nanoparticles into conventional heat transfer fluids such as water, ethylene glycol, and engine oil [1]. Most of the studies on a heat transfer of nanofluids have been concentrated on the nucleate boiling region and the CHF phenomenon. A quenching phenomenon is important for analysis of the reflood phase associated with the emergency cooling in water-cooled nuclear reactor core under a loss of coolant accident and the reflood is happened when water refills the reactor vessel and quenches the fuel rod at the time of the severe accident in nuclear power plant. The use of other fluids instead of water for the quenching experiment in the sphere and rodlet specimens has been investigated by many researchers [2-6]. In this work, we have observed a quenching phenomenon of a hot vertical tube during a reflood using SiC/water nanofluid as a coolant, instead of water.

Experiments were conducted to investigate the effect of SiC/water nanofluid on reflood heat transfer in a long vertical tube. The cause selecting SiC nanoparticles is that applying SiC as a cladding material for a light water nuclear reactor is considering because the resistance of SiC to the high-temperature and high-radiation environment is good. 0.01 volume fraction (%) SiC/water nanofluid was prepared by two-step method.

2. Experiment

2.1 Preparation of the Nanofluids

The process of preparation of SiC/water nanofluid is as follows: (1) weigh the mass of SiC nanoparticles by a digital electronic balance; (2) put SiC nanoparticles into the weighed water and prepare the SiC/DIW mixture; (3) sonicate the mixture continuously for 6 hours with sonicator to obtain uniform dispersion of nanoparticles in water.

2.2 Reflood Test

Fig. 1 shows the reflood test apparatus. The test section are made of SS 316 tube (the inner diameter : 10.206 mm and the heating length : 1,300 mm), and are directly heated by a DC passing through the tube wall. In order to measure the tube wall temperature, the nine K-type ungrounded thermocouples (TCs) with a sheath outer diameter of 0.5 mm are attached to the outer wall surface at intervals of 118 mm.

The experimental procedure is as follows. The heated section was heated up to 620 ℃ ~ 720 ℃ (The standard TC is second TC from below and this was heated up to almost 720 ℃), and then the cold working fluids of the temperature of 20 ℃ in the coolant reservoir was injected into the test section by the pump. Just before the working fluids reached the first TC, the dc power supplied to the tube was switched off. The injection flow rate (3 cm/s) was controlled by pump and the needle valve in the upstream of the test section. The total amount of each fluid was 2 liters. Two runs of the experiment were performed for each condition (water and SiC/water nanofluid).

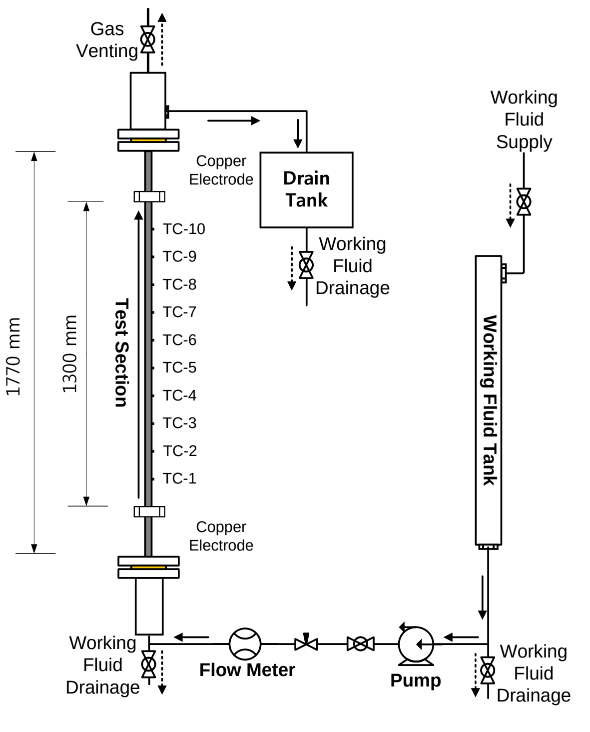

Fig. 1. Schematic diagram of the reflood test apparatus.

3. Results and Discussion

The wall temperature behavior for SiC/water nanofluid refloods was compared with those for the water refloods.

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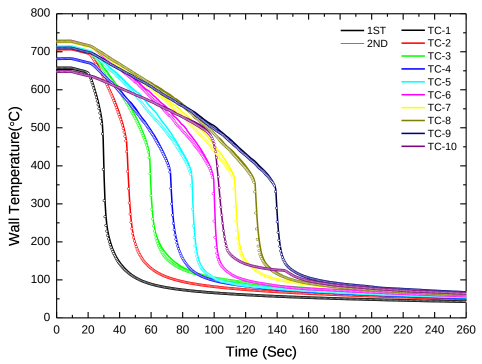

Fig. 2. Wall temperature variations for repetitive runs during water reflood (injection flow rate : 3 cm/s).

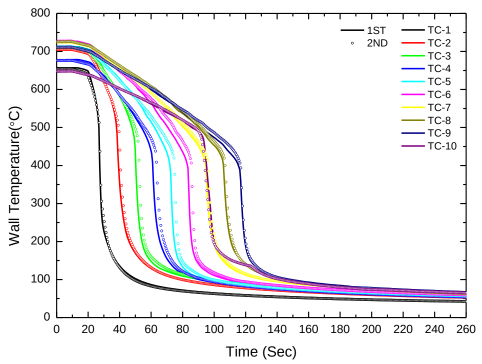

Fig. 3. Wall temperature variations for repetitive runs during SiC/water nanofluid reflood (injection flow rate : 3 cm/s).

Fig. 2 and Fig. 3 show the wall temperature variations for repetitive runs during water and SiC/water nanofluid reflood when the injection flow rate is 3 cm/s. As shown in Fig. 2 and Fig. 3, the wall temperature with three runs of the experiment was nearly same. Table 1 shows the comparison of quenching velocity about water and SiC/water nanofluid. As shown in Table 1. The quenching time was faster in 20 seconds for SiC/water nanofluid compared with water.

Table 1. The comparison of quenching velocity about water and SiC/water nanofluid.

	Injection Velocity (cm/s)	Quenching Time (seconds)		Quenching distance (cm)	Quenching Velocity (cm/s)	
Water	3	109.49	109.41	99.4	0.90	0.90
		109.34		99.4	0.90	
SiC/water Nanofluid	3	87.79	88.94	99.4	1.13	1.11
		90.09		99.4	1.10	

4. Conclusions

The present works were conducted to investigate the effect of SiC/water nanofluid on reflood heat transfer in a long vertical tube. When the potential application of SiC/water nanofluid comes to Emergency Core Cooling System (ECCS), the situation of interest is quenching phenomena of fuel rods during reflood of emergency coolants.

The following results are obtained.

(1) The reflood tests have been performed using SiC/water nanofluid as a coolant, instead of water. We have observed a more enhanced cooling performance in the case of SiC/water nanofluid reflood.

(2) A more enhanced cooling performance is attributed to a high wettability of a thin layer formed on a heating surface by a deposition of SiC nanoparticles.

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