Effect of Water-based Nanofluids on Reflood Heat Transfer in a Hot Vertical Tube

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1. Introduction

"Nanofluids" could be regarded as an alternative for the effective coolant in the various fields of industry. Those are produced by dispersing nanometer-sized particles in traditional base fluids such as water and show reasonable potential to enhance a boiling heat transfer. Several researchers have carried out experiments to confirm the capabilities of nanofluids for a boiling heat transfer [1, 2, 3, 4, 5]. The general consensus in their researches is that nanofluids enhance the critical heat flux (CHF) significantly, however, they have no significant effect on a heat transfer in a nucleate boiling region. Recent studies have shown that a CHF enhancement is attributed to a high wettability of a thin layer formed on a heating surface by a deposition of nanoparticles [6]. Most of the studies on a heat transfer of nanofluids have been concentrated on the nucleate boiling region and the CHF phenomenon. A quenching (rewetting) 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.

In this work, we have observed a quenching phenomenon of a hot vertical tube during a reflood using water-based nanofluids as a coolant, instead of water.

2. Experiments

Figure 1 shows the reflood test apparatus. The test section are made of SUS 304 tube of 8 mm in the inner diameter and 1000 mm in the heating length, and are directly heated by a direct-current passing through the tube wall. In order to measure the tube wall temperature, the nine K-type ungrounded thermocouples with a sheath outer diameter of 0.5 mm are attached to the outer wall surface at intervals of 100 mm. The heated section was heated up to 600–750 ^{o}C, and then the cold nanofluid of the temperature of 20 ^{o}C in the coolant reservoir was injected into the test section by nitrogen gas pressure. Just before the nanofluids reached the inlet of the heated section, the dc power supplied to the tube was switched off. The injection flow rate was controlled by the nitrogen gas pressure and the needle valve in the upstream of the test section, and was determined from the time variation of the coolant level in the reservoir. In this experiment, water-based SiC and Al_2O_3 nanofluids were prepared for the volume concentrations of 0.1 %.

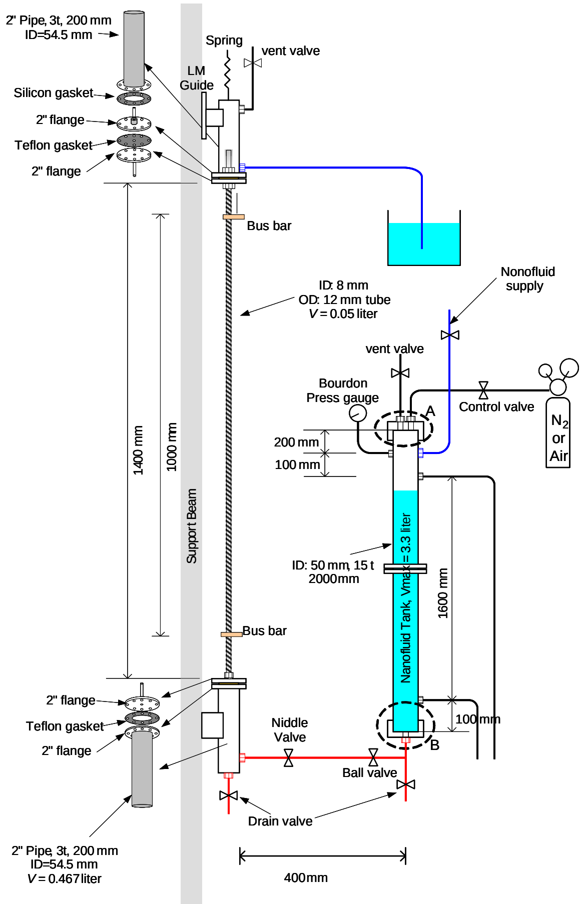

Fig. 1. Schematic diagram of the reflood test apparatus

3. Experimental Results

The injection flow rate may vary during a reflood, since a phase change of the coolant and a back pressure in the test section occur. Figure 2 shows the variation of the coolant level in the reservoir as a function of time during the reflood. The coolant level with time shows the perfect linearity. Therefore, the injection flow rate did not vary in this experiment.

The wall temperature behavior for the nanofluid refloods was compared with those for the water refloods. The variations in the wall temperatures as a function of time for water and SiC nanofluid during the refood are shown in Fig. 3. In the comparison between the water and the SiC nanofluid, a difference in the quenching time (that is, the time required to cool down the hot tube

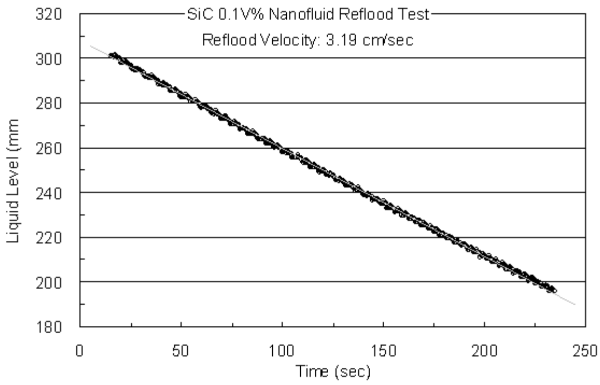

Fig. 2. Time variation of the coolant level in the researvoir

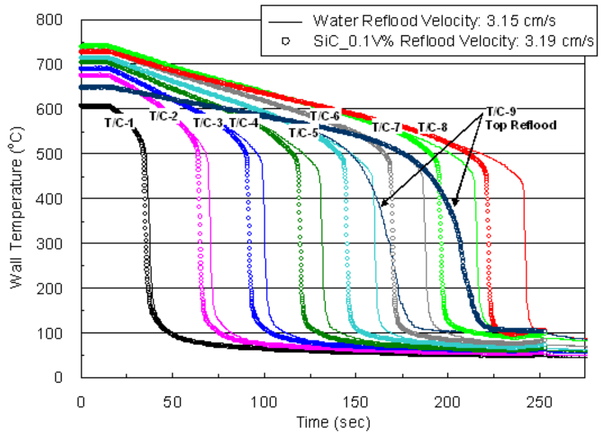

Fig. 3. Wall temperature variations during SiC nanofluid reflood

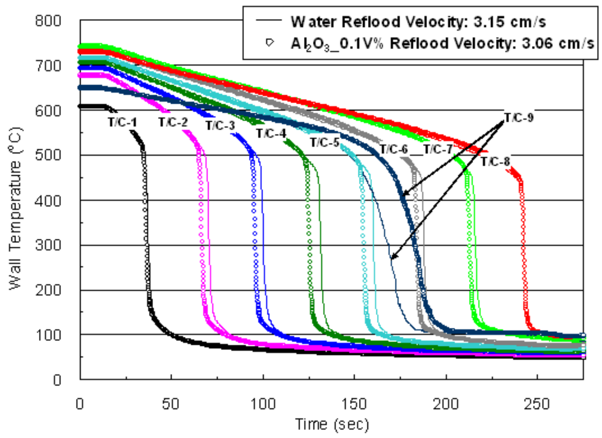

Fig. 4. Wall temperature variations during Al_2O_3 nanofluid reflood

surface from the coolant injection to the termination of a quenching, *Twall*=100 ^{o}C) is not observed at the lower part (T/C-1) of the heated section. However, at the location of T/C-8 in the upper part of the heated section, the difference in the quenching time between the water and the SiC nanofluid shows more than 20 seconds. The top reflood occurs at the location of T/C-9 in the top of the heated section. The experimental result for Al_2O_3 nanofluid in Fig. 4 does not show the clear difference in the quenching time between the water and the Al_2O_3 nanofluid.

4. Conclusions

The reflood tests have been performed using nanofluids as a coolant, instead of water. We have observed a more enhanced cooling performance in the case of the nanofluid reflood. The SiC 0.1 vol. % nanofluid has shown a considerably shorter quenching time, compared with the water.

ACKNOWLEDGMENTS

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