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Pool boiling heat transfer characteristics of vertical cylinder quenched by SiO_2–water nanofluids

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ABSTRACT

This study includes an experimental investigation of the pool boiling heat transfer characteristics of a vertical cylinder quenched by SiO_2–water nanofluids. The experiments are performed through a cylindrical rod, at saturated temperature and atmospheric pressure. As the coolant, pure water and SiO_2–water nanofluid suspensions at four different concentrations (0.001, 0.01, 0.05 and 0.1 vol.%) are selected. The test specimen heated at high temperatures is plunged into cooling fluids at saturated conditions in a pool. The cooling curves are obtained via taking the temperature–time data of the specimen into account. The experimental results indicate that the pool film boiling heat transfer in nanofluids is identical to that in pure water. However, during the repetition tests in nanofluids with high concentrations, the film boiling region disappears, and the critical heat flux increases. In addition, the nucleate pool boiling heat transfer coefficient decreases compared with that of pure water, but a considerable decrease in nucleate pool boiling heat transfer is not observed with the repetition tests. A change in surface characteristics due to the deposition of nanoparticles on the surface has a major effect on the quenching process.

1. Introduction

Boiling is one of the most effective modes of heat transfer, which is used in various industrial applications such as nuclear, chemical and electronic. In these applications, the transport properties of working fluid play an important role in enhancing boiling heat transfer. Developing high-performance heat transfer fluids has been the subject of numerous investigations in the past few decades. The traditional solid–liquid mixtures containing suspended milli- or micro-sized solid particles have higher thermal conductivities than those of base fluids [1]. As the technology of growing nano-sized particles has rapidly developed, suspensions of nano-sized particles in fluids, called nanofluids [2], have been produced. Nanofluids are a new kind of heat transfer fluid containing a small quantity of nano-sized metallic or oxide particles (<100 nm). In recent years, reported studies on the pool boiling heat transfer (BHT) of nanofluids have contained incoherent results, which are briefly presented in the following paragraphs.

You et al. [3] investigated the critical heat flux (CHF) of Al_2O_3–water nanofluids on a 10-mm-square heater under sub-atmospheric conditions. In that study, a dramatic increase (about 200% compared with pure water) in the CHF was observed, while no significant change in the nucleate pool BHT coefficients was determined. Vassallo et al. [4] studied SiO_2–water nanofluids boiling on a 0.4-mm-diameter horizontal Ni–Cr wire at atmospheric pressure. The researchers' results showed a considerable increase in the CHF of the nano- and micro-solutions compared to water and no significant change in the BHT performance at heat fluxes less than the CHF. Bang and Chang [5] performed experiments on a flat plate heater, which was immersed in Al_2O_3–water nanofluids at atmospheric pressure. The researchers reported that the CHF increased in not only horizontal but also vertical pool boiling, but decreased in the pool BHT coefficient. Das et al. [6] investigated the nucleate pool boiling characteristics of Al_2O_3–water nanofluids on a cylindrical cartridge heater. The authors observed that the nucleate BHT deteriorated due to the deposition of nanoparticles on the heated surface. In addition, Das et al. [7] studied the boiling behavior of nanofluids on narrow tubes and observed that the heat transfer performance deteriorated less on narrow tubes.

Wen and Ding [8] carried out pool BHT experiments using Al_2O_3–water nanofluids on 3-mm disc heaters. Contrary to the above studies, these results showed that the heat transfer coefficient increased as the particle concentration increased. Chopkar et al. [9] investigated the pool BHT characteristics of ZrO_2–water nanofluids from a flat surface in a pool. The authors observed that

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