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Pool boiling heat transfer of functionalized nanofluid under sub-atmospheric pressures

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ABSTRACT

A water-based functionalized nanofluid was made by surface functionalizing the ordinary silica nanoparticles. The functionalized nanoparticles were water-soluble and could still keep dispersing well even at the mass concentration of 10% and no sedimentation was observed. An experimental study was carried out to investigate the pool boiling heat transfer characteristics of functionalized nanofluid at atmospheric and sub-atmospheric pressures. The same work was also performed for DI water and traditional nanofluid consisted of water and ordinary silica nanoparticles for the comparison. Experimental results show that there exist great differences between pool boiling heat transfer characteristics of functionalized and traditional nanofluid. The differences mainly result from the changes of surface characteristics of the heated surface during the boiling. A porous deposition layer exists on the heated surface during the boiling of traditional nanofluid; however, no layer exists for functionalized nanofluid. Functionalized nanofluid can slightly increase the heat transfer coefficient comparing with the water case, but has nearly no effects on the critical heat flux. It is mainly due to the changes of the thermoproperties of nanofluids. Traditional nanofluid can significantly enhance the critical heat flux, but conversely deteriorates the heat transfer coefficient. It is mainly due to effect of surface characteristics of the heated surface during the boiling. Therefore, the pool boiling heat transfer of nanofluids is governed by both the thermoproperties of nanofluids and the surface characteristics of the heated surface.

1. Introduction

The concept of nanofluid (nanoparticle suspension) as a working fluid was first advanced by Choi [1] in 1996 due to its anomalous heat transfer characteristics. Since then, intensive researches have been carried out to study the heat transfer characteristics of nanofluids, starting from the thermal conductivity [1–3], then the convective heat transfer [4–7] and now focusing mainly on the phase-changing heat transfer of nanofluids [8–31]. Among them, the research of pool boiling heat transfer of nanofluids is very important subject. Researches of pool boiling heat transfer of nanofluids focus mainly on two aspects: the heat transfer coefficient (HTC) and the critical heat flux (CHF) of nanofluids. Up to now, there exist great differences among the various experimental results and it is hard to obtain the consistency on the boiling heat transfer mechanism.

Researches on the HTC of nanofluids are summarized in Table 1. As is shown, the effect of nanofluids on the HTC varies largely with the HTC enhancement, the HTC deterioration, and no obvious changes and so on when compared to that of the base fluid. Researches on the CHF of nanofluids are summarized in Table 2. As is shown, all researches reported enhancement effect of the CHF compared with the base fluids. The types of nanoparticles and base fluids, the diameter of nanoparticles, the preparation method, the operating conditions and the surface characteristics of the heated surface all make the enhancement ranging at different values.

For traditional nanofluids used in most of previous experiments, nanoparticles tend to aggregate in the fluid due to the van der vaals attraction. The aggregated nanoparticles will settle out of base fluids after a period of time. The surface functionalization technique is a promising way to solve this problem. The current authors have reported a preparing technique to make a kind of functionalized nanofluid that can stay long-term stability [32]. The nanoparticles used were functionalized silica nanoparticles by grafting silanes to the surface of silica nanoparticles. After the surface functionalization process, nanofluids were prepared using functionalized nanoparticles and deionized water. Functionalized nanoparticles were dispersed into deionized water and the solution was kept standing for 12 h with the environmental temperature of 50 °C. Then well dispersed nanofluid can be prepared without any

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