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Pool boiling of Titania-Water-Ethylene Glycol Nanofluids

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Abstract

Pool boiling studies were conducted on horizontal flat copper heaters of various surface roughnesses (Ra). The boiling fluids were dilute suspensions of spherical-shaped Titania and Alumina particles stably suspended in Ethylene Glycol-Water mixtures. Applied surface heat fluxes were ranging upto 189kW/m^2. It was found that nanoparticles deteriorate boiling heat transfer. Nanoparticle deposition on heater is believed to be the most likely reason for observed deterioration.

Keywords: Boiling, water-ethylene glycol, nanofluids, flat heater

Introduction

Boiling is the preferred mode of heat transfer in a wide range of applications due to its ability to transfer larger quantity of heat across a given temperature difference. Surface modifications, which lead to increase in surface area and introduction of bubble nucleation sites, are frequently used as means of enhancing the boiling performance (Bergles, 1997). In recent times, nanofluids have been investigated as a potential replacement for conventional heat transfer liquids. Titania, Alumina, Silica, Zercornia or Carbon nanotubes had been suspended in liquids such as water, ethylene glycol, engine oil, or refrigerants and examined for pool boiling. In few instances an enhancement was reported although more often the outcome was deterioration (Das et al., 2003; Vassallo et al., 2004; Bang & Chang, 2005; Wen & Ding, 2005; Park and Jung 2007). Nevertheless, nanofluids demonstrated large enhancement in the critical heat flux (CHF) in almost all experiments (You et al., 2003; Milanova & Kumar, 2005). Subsequent investigations have revealed that the change in boiling heat transfer performance and the CHF was caused by surface modifications that occurred due to nanoparticle deposition on heaters (Kim et al., 2007; Narayan et al., 2007; Golubovic et al., 2008). Nanoparticle deposition alters the heater roughness leading to changes in capillary wicking effect and nucleation site density. In addition to this, nanoparticles gathering and structuring under a growing bubble may exert upward pressure on the bubble from underneath, prompting it to disjoin from the heater earlier than usual (Sefiane, 2006). A comprehensive literature review on this subject, which was summed up above, indicates the need for finer and more systematic study into the mechanisms behind boiling of nanofluids. To shed more light onto this, we recently conducted pool boiling experiments using Titania-Water-Ethylene Glycol nanofluids on flat copper heaters. First part of our findings are presented below.

Materials and Methods

Stable Titania-Water-Ethylene glycol (EG) nanofluids were formulated in a way similar to that outlined in Chen et al (2007). Tests reported here were having EG concentrations of 25wt% or 10wt% (respectively called WEG25 and WEG10). Dynamic light scattering measurements showed that the particle sizes in the nanofluids were around 125nm±10%. The circular flat Copper heaters of 4.9cm^2 surface area were polished to achieve Ra=40nm (smooth) and Ra=275nm (rough). The experiments were conducted under atmospheric pressure in the apparatus shown in Fig 1 for heat fluxes ranging from 52 to 189kW/m^2.

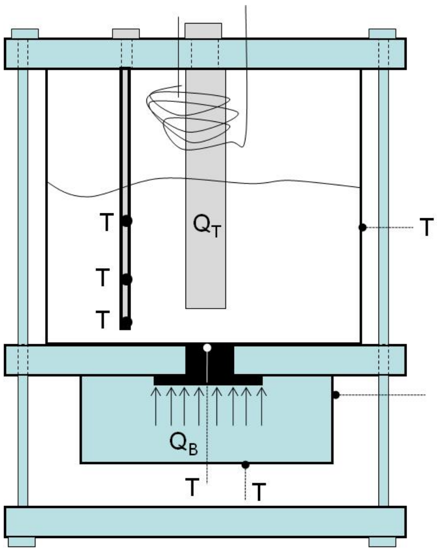

Fig 1: Pool boiling test rig; T-thermocouples, Q_T-auxiliary heater, Q_B-test surface heater

Accuracy of thermocouples was ±0.1C. Temperature data were logged using NI SCXI-1000 data logger and was subsequently displayed on PC using LabView. Power input to the test surface (Q_B) was measured using a power meter. Surface heat flux was calculated by dividing the power meter reading by surface area. Firstly the WEG was boiled on fresh heater, followed by nanofluid and once again the WEG.

Experimental results

Fig 2 and Fig 3 show the experimental data for Titania 0.1wt%-WEG25 on rough heater and Titania 0.1wt%-

WEG10 nanofluid on smooth heater. ΔT indicates the difference between heater and saturation temperature. The errors bars on Fig 2 were obtained after repeating each experiment for three times. It is obvious from figures that the nanofluids in both instances have displayed systematic degradation of heat transfer throughout all heat fluxes. Moreover, boiling data for WEG on nanofluid-boiled heater is reasonably agreeing with nanofluid. This is one indication that the heater has altered during nanofluids boiling and that alteration stayed on through subsequent experiments. Visual observations of the surfaces confirmed particle deposition.

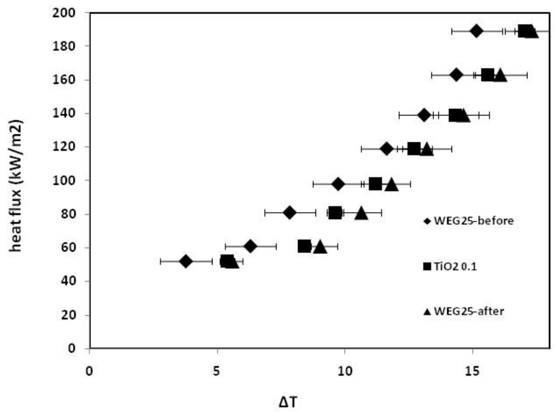

Fig 2: Titania 0.1wt%-WEG25 nanofluid on rough heater

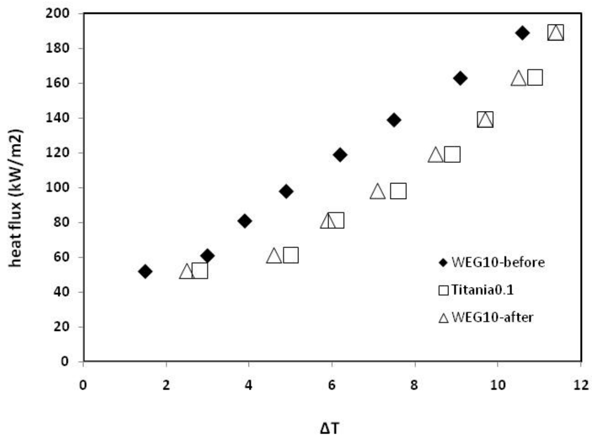

Fig 3: Titania 0.1wt%-WEG10 nanofluid on smooth heater

We further used the experimental data for Titania0.1%-WEG25 on rough coupon to investigate the relationship between boiling duration and amount of deposition. This is illustrated in Fig 4 for three sequential experiments. Neither the coupon nor the nanofluid was changed in-between. After the 1st run, a slight enhancement is demonstrated. Moreover, the overlapping data for 2nd and 3rd runs indicate that the particle deposition effect has diminished after the 1st run. This reveals important information.

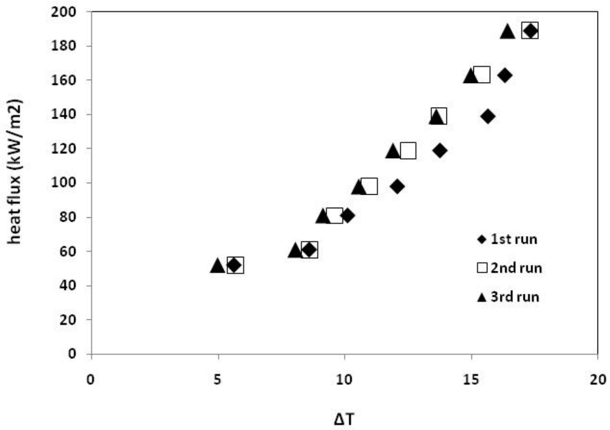

Fig 4: Deposition effect; Titania0.1wt%-WEG25

Conclusions

WEG-based dilute Titania nanofluids were boiled on flat copper heaters. Boiling heat transfer for nanofluids was found to be inferior to that of the base liquid. The deterioration is likely to have caused by particle deposition on heater. Repeated boiling of nanofluids however did not yield excessive deposition. Surface measurements are being underway to draw more conclusive evidence.

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