Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Boiling phenomena with the surfactant and nanoparticles

Sung Dae Park, Sarah Kang, Seung Won Lee, In Cheol Bang*
Ulsan National Institute of Science and Technology(UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulasn Metropolitan City 689-798, Republic of Korea
**Corresponding author: icbang@unist.ac.kr, sdpark@unist.ac.kr*

1. Introduction

It has been known that critical heat flux(CHF) in pool boiling is often enhanced when nanoparticles are dispersed in the conventional fluid. But it is unclear that how to change the heat transfer coefficient (HTC) during pool boiling. Some researcher reported studies about enhancement of HTC.[1] Opposed results are reported.[2] And several papers have shown little enhancement. [3]

On the other hand, addition of small amount of surfactants in water can enhance the HTC. That is the reason that these surfactants cause the surface tension depression. This leads to increase of rate of formation of vapor nuclei in the boiling. However, because vigorous generation of bubbles interrupts the presence of the surfactant on the heat surface, the surfactants have little effect on the CHF.

In this work, we treated the effect of fluid mixture with surfactant and nanoparticles during the boiling. This present paper is aimed that advantages of critical heat flux and heat transfer coefficient enhancement are satisfied at the same time. Additionally, we expect that it is possible to make the fluid with high thermal conductivity and low viscosity by mixing the surfactant and nanofluid. But it is not covered in this work.

2. Description of experiment

2.1 Preparation of test fluids

Alumina nanofluid is prepared by dispersing nanoparticles into the distilled water as a base fluid. Alumina nanoparticles were manufactured by Sigma Aldrich Corporation(size < 100nm, thermal conductivity = 36 W/m· K). The concentration of nano fluid is 0.01 v%. The prepared nanofluid was performed for 5h with the sonication processing for the more uniform and stable dispersion.

Sodium laurilsulfate or sodium dodecyl sulfate (SDS) is used as surfactant additives in this work. SDS is anionic surfactant. SDS were manufactured by Sigma Aldrich corporation (99+%). It has critical micelle concentration(CMC) at 0.0082M[4] and critical micelle temperature(CMT or Krafft point) at 38℃.[5] To know the effect of surafactant with nanoparticle quantitatively, same amount of mass(0.0013771M) of surfactant with nanoparticles is added to the base fluids such as water and Al_2O_3 nanofluid. We control the pH of fluid mixture with surfactant and nanoparticle to prevent a cluster using NaOH solution.

2.2 Experimental procedure

The heating method on test section is joule heating of nichrome (NiCr) wire. The wire of 0.49mm in diameter was horizontally suspended on electrodes. Data obtaining from the data acquisition device which is connected to the upper part of electrodes and standard resistor is saved and analyzed.

Before the experiments, the state of fluid was maintained at saturated temperature. Heating time remains the same during increasing the equal heat flux. The heat flux was calculated by obtained data in data acquisition system using the Eq(2).

$$q'' = \frac{I^2 R_w}{\pi D L} \qquad (1)$$

where R_w is wire resistance, V is measured voltage, I is measured current. D is the diameter of wire. L is the length of heated wire.

3. Results and discussion

The CHF of distilled water, SDS solution, Al_2O_3 nanofluid and fluid mixture (Al_2O_3+SDS) was measured at pH7 and pH11 under the atmospheric pressure. Figure 1 shows characteristic boiling phenomena of these fluids.

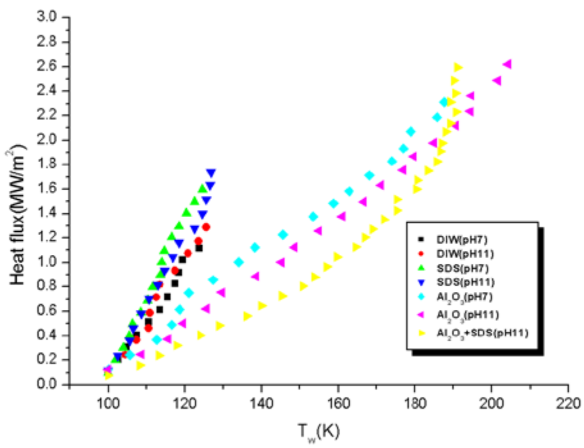

Figure 1. Boiling Curve of test fluids

$$q''_{zuber} = \frac{\pi}{24} \rho_g^{1/4} h_{fg} \sqrt[4]{g\sigma(\rho_f - \rho_g)} \qquad (2)$$

where q''_{zuber} is the CHF of the distilled water, ρ_g is the gas density, ρ_f is the liquid density, h_{fg} is the latent heat from liquid state to gas state, σ is the surface tension.

The CHF of distilled water matches exactly to Zuber's prediction correlation (Eq,2). [6] It can be valid reference to compare to other results.

In the all cases of pH11, CHF is enhanced about 100~200kW/m^2 as compared with pH7 of same fluid. Hydrogen and oxygen gas are formed from neutral state of OH-. It causes the change of CHF in the pool boiling. [7]

When SDS is added in the fluid, HTC is enhanced. As we mentioned above, surface tension is related to HTC. Westwater assumed the HTC relationship with surface tension(Eq.3) [8]

$$h \propto \sigma^n \quad (3)$$

CHF of SDS solution is far from the generally well-known results. But, there are some results reporting the CHF enhancement of surfactant solution in pool boiling. [9]

In this work, the heat transfer coefficient of nanofluid is decreased conspicuously. And there is no enhancement of the HTC and CHF when adding SDS surfactant to Al_2O_3 nanofluid. As a result of that, the surfactant would hardly influence on nanofluid.

4. Conclusions

The following results are obtained.

(1) SDS surfactant effects on the HTC and CHF.
(2) It is confirmed that concentration of H+, OH- is the variable of the change of CHF.
(3) HTC of dispersed Al_2O_3 nanofluid degenerates at comparing the HTC of distillated water during pool boilng.
(4) SDS surfactant hardly influence on nanofluid.

To elucidate above conclusions, additional work is needed; pool boiling test under a various concentration of surfactant solution, use of cationic, nonionic and zwitterionic surfactant, exception of pH variable.

REFERENCES

[1] Z. Liu, J. Xiong, R. Bao, Boiling heat transfer characteristics of nanofluids in a flat heat pipe vaporator with micro-grooved heating surface, Int. J.Multiphase Flow 33 (2007) 1284–1295.
[2] Z. Liu, J. Xiong, R. Bao, Boiling heat transfer characteristics of nanofluids in a flat heat pipe evaporator with micro-grooved heating surface, Int. J.Multiphase Flow 33 (2007) 1284–1295.
[3] M. Chopkar, A.K. Das, I. Manna, P.K. Das, Pool boiling heat transfer characteristics of ZrO2–water nanofluids from a flat surface in a pool, HeatMass Transfer (2007).
[4] P.Mukerjee and K. J. Mysels, "Critical Micelle Concentration of Aqueous Surfactant Systems", NSRDS-NBS 36, US. Government Printing Office, Washington,D.C., 1971.
[5] Baojiao G, Yaming Y, Liding J Studies on micellar behaviour of anionic and surface-active monomers with acrylamide type in aqueous solutions. Colloid Surfaces A: Physochem Eng Aspects (2006)
[6] N. Zuber, Hydrodynamic aspects of boiling heat transfer, AEC Report No. AECU-4439 (1959).
[7] D. Milanova and R. Kumar, Role of ions in pool boiling heat transfer of pure and silica nanofluids, Appl. Phys. Lett. 87 (2005)
[8] J.W. Westwater, Advance Chemical Engineering. vol. I, Academic Press, New York (1955)
[9] H Sakashita, A Ono, Y Nakabayashi, Measurements of critical heat flux and liquid-vapor structure near the heating surface in pool boiling of 2-propanol/water mixtures, Journal of Heat and Mass Transfer(2009)