Experimental study of single bubble behavior in the pool boiling

Ji-Hwan Park*, Faraz Aziz, Daeseong Jo
* School of Mechanical Engineering, Kyungpook National University
wtsakura@naver.com

1. Introduction

The immersion cooling [1] method is important in the mechanical field such as electrical vehicle [2] to cool battery. Specially, the cooling using the boiling [3] is interested to cool electrical vehicle battery recently. When the working fluid was reached in the saturated liquid temperature condition, the surface temperature is kept slightly higher above the liquid temperature. By applying characteristic of the boiling phenomena, many researches performed two - phase immersion cooling experiment to cool surface.

The pool boiling [4] is classified as single – phase convection boiling, nucleate boiling and transition boiling. Also, the nucleate boiling is classified as single bubble behavior and bubble column with increasing the heat flux. In this paper, single bubble behaviors such as contact angle and bubble diameter were investigated to calculate the force acted on the vapor. The parameters for the bubble behavior were calculated by using the image processing in the MATLAB R2020b.

2. Experimental facility and test condition

To investigate the single bubble behavior, pool was constructed. The pool consisted of heating jacket, preheater, thermocouples, transparent window and PCB heater. The heating jacket keeps the pool temperature constant and the preheater increases the liquid temperature. From the thermocouples, liquid temperature and pool temperature were measured, the bubble behaviors were investigated from the transparent window. In the PCB heater, the copper was polished to have the similar roughness. The working fluid was used to distilled water.

The liquid temperature kept saturated temperature condition constant by using the preheater. In the saturated temperature condition, the power of the PCB heater increased until single bubble behavior was shown.

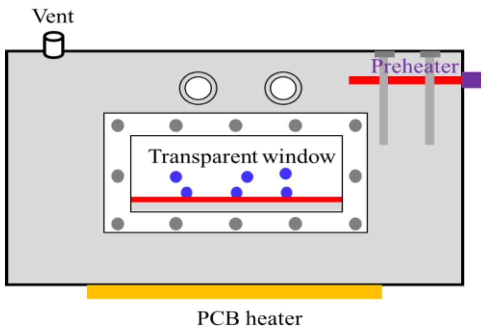

Fig 1. Pool facility

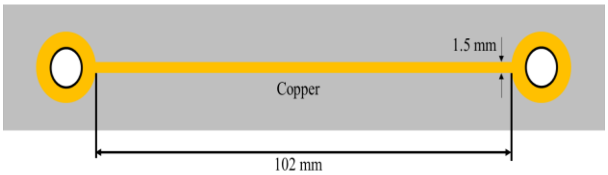

Fig 2. PCB heater

3. Data reduction

To calculate the surface temperature in the PCB heater, equation [5] was used as follows

$$R = R_{ref}\left\{1 + \alpha(T - T_{ref})\right\}. \qquad (1)$$

The R_{ref} and the T_{ref} is reference resistance and temperature, respectively in the saturation liquid temperature. The α is temperature resistance coefficient the R is surface resistance along the surface temperature. From these parameters, surface temperature (T) can be calculated.

4. Results and discussions

By using the preheater, liquid temperature was kept to saturation condition. From the obtained data, the average surface temperature was calculated at the 0.941 kW/m^2. The difference between liquid and surface temperature was about 26 ℃ as shown fig 3. At the heat flux, the vapor was formed on the heated surface in this paper.

From the obtained images, image processing was performed to calculate the bubble behavior as shown fig 4 and 5.

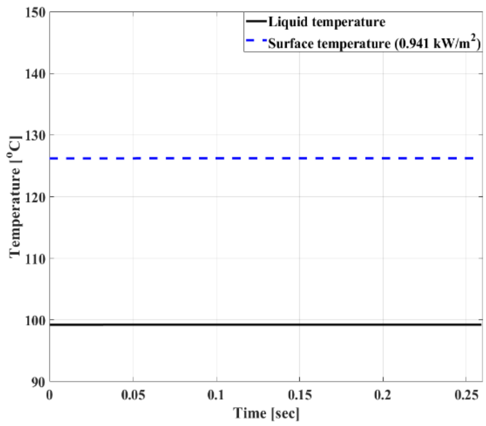

Fig 3. The liquid and surface temperature

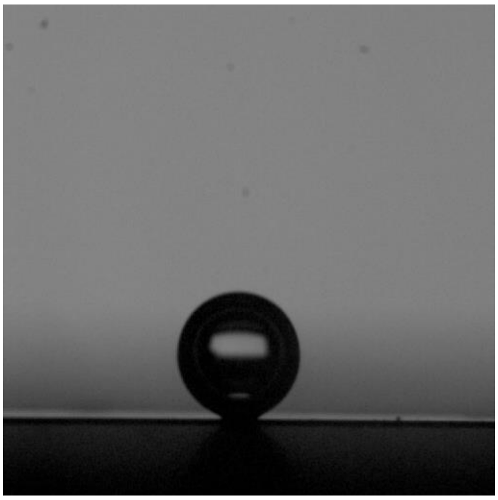

Fig 4. The bubble on the PCB heater

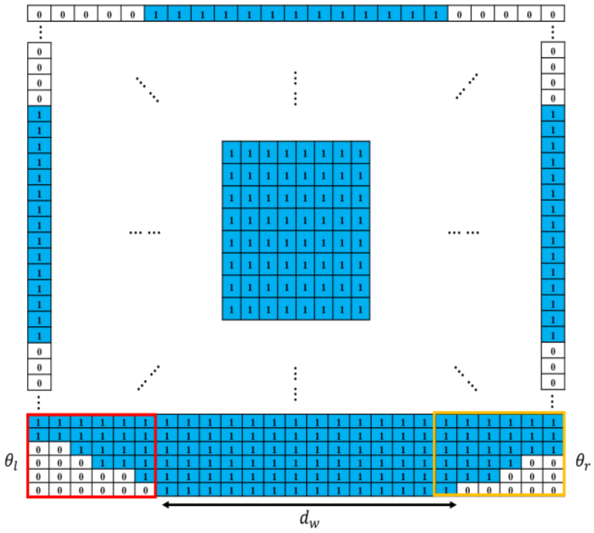

Fig 5. Binarized vapor

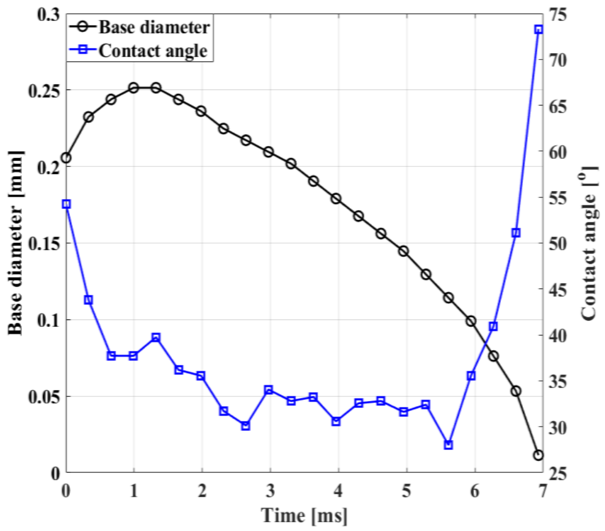

Fig 6. Base diameter (d_w) and contact angle

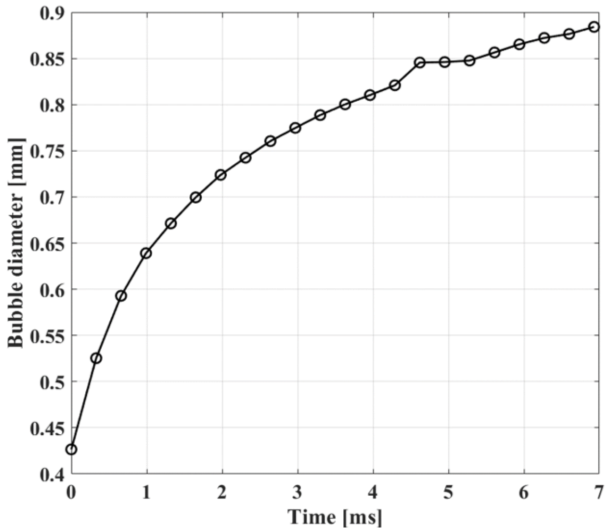

Fig 7. Bubble diameter

In the fig 5, number 1 shows the vapor and number 0 shows liquid. The 3 phase contact point is intersection between solid, liquid and vapor. From this point, linear lines were made in each floor. When lines between linear line and the heated surface were made, these lines were set as contact angle. When the contact angles were calculated in each floor, the contact angles were calculated to be averaged until contact angles did not be changed. Also, the base diameters were calculated along the time. With changing base diameter, the contact angle was changed.

Fig 6 shows relation between contact angle and base diameter along the time. When the vapor was formed firstly on the heated surface, contact angle was high relatively. However, contact angle decreased along the time. Before the vapor was departure, the contact angle increased and was the highest. When the base diameter increased, the energy was received to vapor. The volume rate of vapor increased sharply. However, when the base diameter decreased, the energy was received to be low. Therefore, volume rate of vapor decreased. Fig 7 shows average bubble diameter by using the sauter mean diameter concept and reconstruction.

In the next research, the forces such as surface tension and buoyancy force will be calculated by using the bubble diameter and contact angle at the different inclination heater.

5. Conclusion

In the pool boiling, the bubble behaviors was investigated and calculated by using the image processing. From the obtained data, bubble behavior was calculated. The base diameter increased and decreased along the time. With changing the base area, volume rate was changed because the input and output of energy was changed. Also, contact angles were changed along the time. When the vapor was formed on the heated surface, the trend of contact angle decreased and increased. Also, when the vapor was departed, contact angle was the highest.

REFERENCES

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