Image Processing Technique for a Droplet Size and Velocity Measurement in a Air-Water Droplet Flow

H. K. Cho[*] , Y.J.Choo, C.-H. Song
Korea Atomic Energy Research Institute,1045 Daedeok-daero, Yuseong-gu, Daejon, 305-353,Korea
**Corresponding author: hkcho@kaeri.re.kr*

1. Introduction

During the reflood phase of a postulated loss of coolant accident in a nuclear reactor, the entrainment of liquid droplets can occur at a quench front of a reflooding water. It is widely recognized that the behavior of the entrained droplet crucially affects the reflood heat transfer phenomena by decreasing the superheated steam temperature and interacting with a rod bundle and spacer grids. For this reason, various experimental and numerical studies have been performed to predict the droplet behavior such as the droplet size, velocity, droplet fraction, etc.

An experiment about the droplet behavior inside a heated rod bundle is planned to investigate the interaction between the droplets and spacer grids. Instead of simulating a quench front of a reflooding water, a droplet injector will be utilized for the experiment. The major measuring parameters of the experiment are the droplet size, droplet velocity, droplet frequency, droplet fraction, superheated steam temperature and so on.

In the present study, a preliminary study of the droplet experiment was conducted to establish a measurement technique for a droplet size and velocity. The preliminary test was performed with a droplet generator and the size and velocity of the droplets were measured by an image processing technique. In this paper, the image processing technique is introduced.

2. Experiment

A droplet generator was fabricated to provide droplets with a known droplet Sauter mean diameter. Fig.1 shows the droplet generator and its schematic diagram. The droplets are generated by a Rayleigh jet break-up instability and its SMD is approximately [1]

$$D_{drop} \approx 1.9 D_{jet} = 0.3534 \text{ mm} . \quad (1)$$

Redlake MotionPro X4 high speed camera was utilized to obtain images for the image processing. The movies were taken with a 1000 frames per second frame rate and a 20 μm shutter speed.

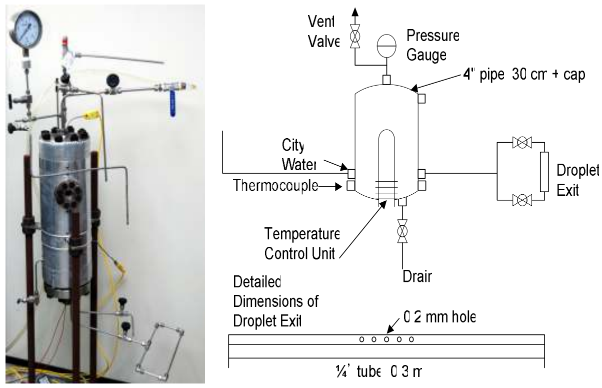

Fig. 1 Droplet generator

3. Droplet Size Measurement

Fig.2 shows the procedure of the image processing for the droplet size measurement. Fig.2-(a) is the original image and Fig.2-(b) the filtered image with sobel filter and median filter. After that the filtered image was binarized by Otsu's method [2] (Fig.2-(c)). To remove the defocused droplet from the images, the intensity profile across the boundary of a droplet was examined as shown in Fig. 2-(d). If the slope of the normalized intensity profile is less than 1, the droplet is regarded as defocused. After eliminating the defocused droplets, properties of each droplet such as the centroid, equivalent diameter, eccentricity, etc can be calculated. Fig. 3 shows the shape of the liquid jet and jet-break up and Fig. 4 shows the measured droplet diameter from the image processing.

4. Droplet Velocity Measurement

Two-dimensional velocity of a droplet can be calculated from the two consecutive images by dividing the centroid displacement of a droplet in the two images by the time difference of the images. The size and eccentricity of a droplet were used to figure out two matching droplets in the two images. It is likely to happen occasionally that more than two droplets have similar size and eccentricity in the second image, so that it is impossible to find a pair of matching droplets simply from those information about the droplets. In that case, the match probability method developed by Baek and Lee was utilized [3]. Fig. 5 shows a typical example of the velocity measurement.

5. Conclusion

In the present paper, an imaging processing technique to measure the size and velocity of droplets is introduced, which is to apply to a droplet behavior measurement test. The applicability of the technique will be tested in an upward air-water droplet flow in the near future.

Acknowledgements

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References

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[3] S.J. Baek and S.J. Lee, New Two-frame Particle Tracking Algorithm Using Match Probability, Exp. Fluids, Vol.22, pp.23~32. , 1996

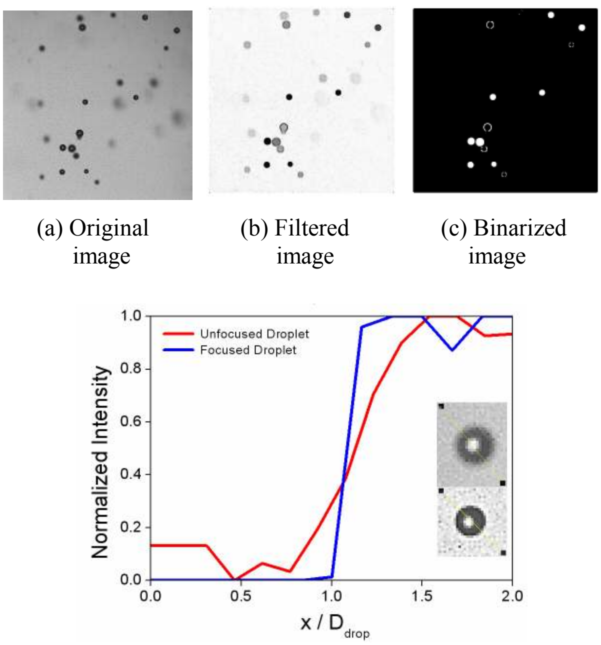
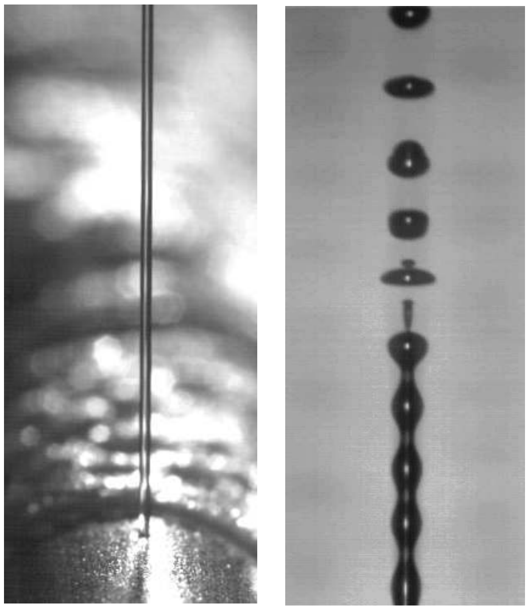


Fig. 2 Image Processing Procedure



(a) Liquid jet (b) Jet Break-up

Fig. 3 Liquid jet and jet break-up

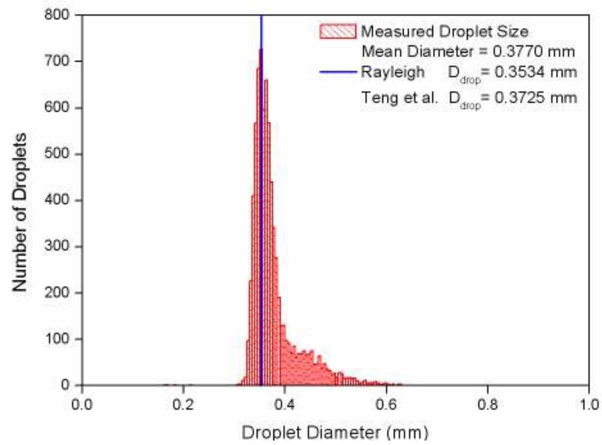
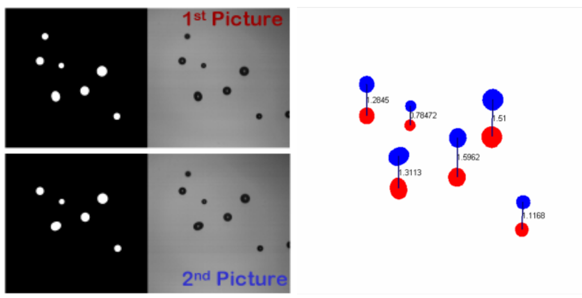


Fig. 4 Histogram of measured droplet diameter



(a) Original image (b) Calculated velocity

Fig. 5 Example of velocity measurement