Feasibility Test for Visualization of Two-Phase Flow Inside Metallic Mini-Tube by Neutron Radiography

TaeJoo Kim,a Kaoru Yasuhara,b YongMi Jung,c Moo Hwan Kim,a
a Dept. Mech. Eng., POSTECH, San31 Hyojadong, Pohang, Kyungbuk, dragon11@postech.ac.kr
b Inst. for Mat. Chem. and Eng., Kyushu Univ.,6-1, kasuga-koen, Kasuga, Fukuoka, Japan, caoru@yz.yamagata-u.ac.jp
c School of Environment Eng., POSTECH, San31 Hyojadong, Pohang, Kyungbuk, psyche@postech.ac.kr

1. Introduction

Neutron radiography is one of non-destructive methods. It is similar to X-ray and γ-ray radiography in that they use the difference in attenuation characteristics of materials. However, there is great difference between them because the transmission mechanism is different. Figure 1 shows the mass attenuation coefficients of thermal neutron, X-ray, as well as γ-ray in various elements. The mass attenuation coefficients of X-ray and γ-ray monotonically increase with the atomic number since they interact with electrons. Thus X-ray and γ-ray image methods don't supply sufficient contrast for light element (for example hydrogen and its compounds) which is surrounded by heavy element. On the other hand, that of thermal neutrons depends largely not on electrons but on the nucleus. Especially thermal neutrons easily penetrate most of metals, while they are attenuated well by such materials as hydrogen, water, boron, gadolinium and cadmium.

The purpose of this study is to check the possibility for the visualization inside metallic mini-tube using neutron radiography. The influences of metal type and tube diameter are investigated on this experiment.

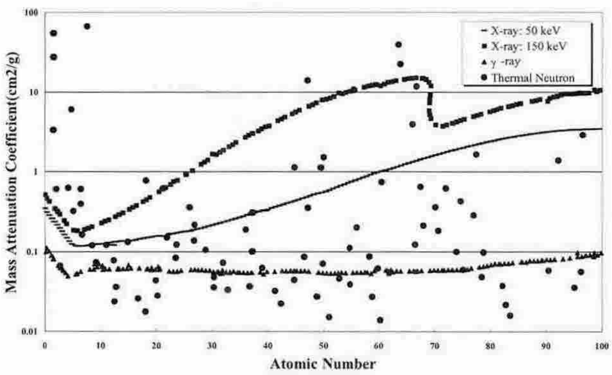


Figure 1. Comparison mass attenuation coefficient among thermal neutron, X-ray, and γ-ray

2. Experimental Set-up

Figure 2 shows the schematics of experiment apparatus. Experiment apparatus is composed chiefly of neutron beam source, test section, converter, mirror box and camera. BNCT (Boron Neutron Capture Therapy) port of HANARO in KAERI (Korea Atomic Energy Research Institute) is used for Neutron Beam source facility. Thermal neutron radiated from Beam port transmits and is attenuated across the test section, and then converted to image of visible light by the converter. Image of visible light is reflected at 90 degree in the mirror box and taken by the digital camera.

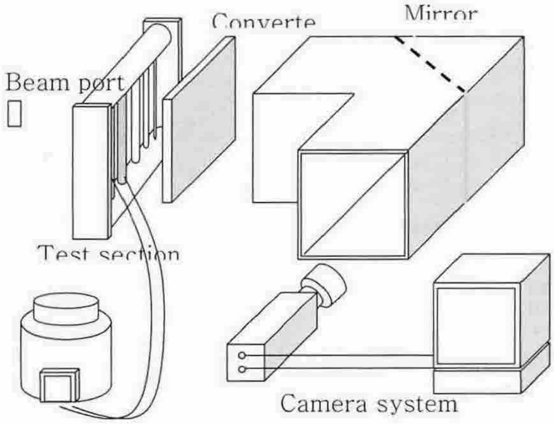


Figure 2. Schematic diagram of experimental apparatus:

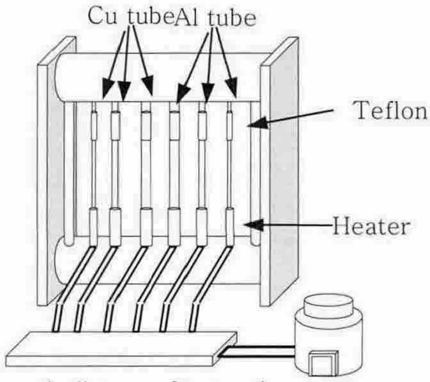


Figure 3. Schematic diagram of test section:

Figure 3 shows the schematics of test section. Upper tank and bottom tank are connected by two revolving tube and 6 test tube. Triple different diameter (1/16", 1/8" and 1/4") cupper and aluminum tubes are used for test tube. Each test tube is winded by hot wire at the bottom for heating and attached Teflon tube at the foreside for macroscopic observation. Heat flux of hot wire is adjusted adequately by power supply. Tank is filled with refrigerant HFC-134a. Refrigerant is heated by the hot wire and evaporate then flow up through the test tube. Refrigerant inside upper tank flows down to bottom tank through the revolving tube. Experiment is conducted by adjusting the heater input from 4.5~64W.

3. Results and Discussion

Figure 4 shows the original test image at 1/4" Al tube with 49W of heater input. Since the mass attenuation of aluminum is small, the tube is underdeveloped. Every photographic image is too dark and unclear, because the light intensity of converter is too low on this experiment. Therefore the post-processing was required to display the clear image.

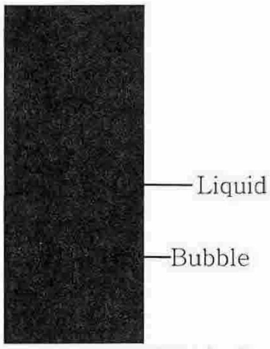
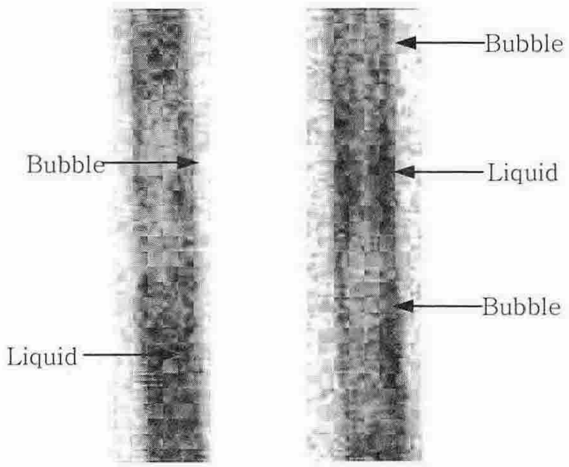


Figure 4. Original test image at 49 W, 1/4" Al tube:

Figure 5 is post-processing images at 1/4" Al tube with 25 and 64W of heater input, respectively. When the test was performed, image intensifier was used due to too small light intensity. However, it also amplified noise. As the result, intensified images are unclear, on the other hand, the motions of bubble and liquid can be discriminated at each image. Fig. 5 shows Bubble of image b) is much and larger than that of a). Moreover these images are real situation occurring inside metallic tube. This direct information is the merit of neutron radiography.

At current study, three kinds of tube size (1/16", 1/8", and 1/4") and two kinds of tube materials (Al and Cu) are tested. However, it is difficult to visualize the inside of tube as tube size is smaller than 1/4" because of low light intensity, furthermore, the mass attenuation coefficient of copper is higher than that of aluminum. Consequently, it is difficult to determine the inside of copper tube. If tube size is enough large (for example larger than 1/4"), motion of bubble and liquid inside copper tube can be visualized. It is required to optimize the experimental method for small tube size and high attenuation materials.



a) 25W b) 64W

Figure 5. Two-phase image at 1/4" Al tube: a) 25W, b) 64W:

4. Conclusion

The neutron radiography technique was used to visualize the inside metallic tube. On this study, three and two kinds of tube size and materials were tested by Neutron radiography. From this study, it's known that the neutron radiography is a good technique to visualize the inside metallic tube. Moreover it is the first time to visualize the mini-tube using the neutron radiography. Post-processing images at 1/4" Al tube with 25 and 64W of heater input shows Bubble of image with 64W is much and larger than that of 25W. In case of below 1/4", the two phase phenomena couldn't be visualized due to low light intensity. Therefore it is required to optimize the experimental method for mini-tube and high attenuation materials to visualize.

REFERENCES

[1] T. Hibiki, K. Mishima, Feasibility of high frame-rate neutron radiography by using a steady thermal beam with 10^6 n/(cm^2s) flux, Nucl. Instr. and Meth., Vol.**369**, 186-194, 1996

[2] K. Mishima, T. Hibiki, Quantitative limits of thermal and fluid phenomena measurements using the neutron attenuation characteristics of materials, Exp. Therm. and Fluid Sci., Vol.**12**, 461-472, 1996

[3] T. Hibiki, K. Mishima, H. Nishihara, Measurement of radial void fraction distribution of two-phase flow in a metallic round tube using neutrons as microscopic probes, Nucl. Instr. and Meth. Vol.**399**, 432-438, 1997

[4] K. Mishima, T. Hibiki, Y. Saito, H. Nakamura, M. Matsubayashi, The review of the application of neutron radiography to thermal hydraulic research, Nucl. Instr. and Meth., Vol.**424**, 66-72, 1999

[5] H. Asano, N. Takenaka, T. Fujii, Y. Shibata, T. Ebisu, M. Matsubayashi, Visualization and measurement of refrigerant flow in compression-type refrigerator by neutron radiography, Nucl. Instr. and Meth., Vol.**424**, 98-103, 1999