Development of Two-Dimensional Void Profile Measurement Technique using Impedance

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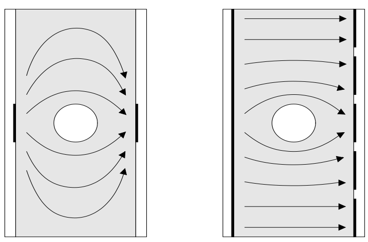
1. Introduction

Because of the difficulty in prediction of two-phase flow phenomena, measurement of local void fraction has been an important issue in many industrial applications, especially in nuclear reactor design and safety. In order to verify currently being developed computational safety analysis code, SPACE, a test section of slab geometry for air-water two phase flow called DYNAS was built in KAERI. The geometry has width and height of 1.43m × 1.43m, and 0.11m depth. The major measurement parameter is two dimensional void fraction profile. In the present research, a simple impedance based void fraction measurement technique for the geometry was developed and verified, and a measurement instrument with 64 channels having 100 Frame/sec sampling period was fabricated.

2. Developements and Experiments

2.1 Electric fields

In the case of slab geometry, general channel to channel impedance measurement approach is not a good choice since there are too many current paths between the electrode pair thus, the impedance is not very sensitive to the local void fraction.



(a) no guard electrodes, (b) with guard electrodes
Fig. 1 Electric fields distribution of two cases

By applying guard electrodes, electric fields are forced to spread straight, and impedance become sensitive to the local void fraction as well as the influence of the neighboring channels becomes lower. Another advantage of this method is that it is possible to measure the impedance of each electrode pairs simultaneously. It is very important to enhance measurement speed especially when the geometry is large and it requires high spatial resolution.

2.2 Void fraction hypothesis

Conductance of a conductive media is well known as Eq. (1).

$$G = \frac{1}{R} = \sigma \frac{A}{L} \quad (1)$$

Based on the fact that the conductance is proportional to the cross sectional area that current passes through, a hypothesis was made that it will be proportional to the liquid fraction and, thus, the void fraction can be expressed as Eq. (2)

$$\alpha \approx 1 - \frac{Gx}{G\max} \quad (2)$$

2.3 Circuits

To measure ion conductance, AC based conductance measurement circuits are required. Fig. 2 shows the schematic diagram of the circuits.

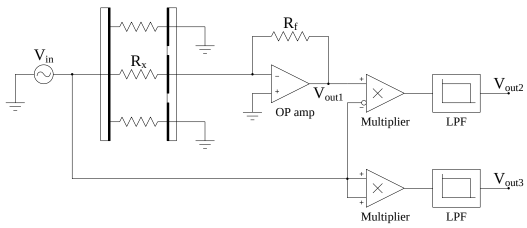


Fig. 2 Ionic conductance measurement circuit

The exciting voltage signal is applied to the entire exciting electrodes, and the measured electrodes are kept ground as well as the neighboring guard electrodes. The signal that passed through OP amp(3), multiplier and Low Pass Filter(4) is proportional to the measuring conductance.

$$V_{out1} = -V_{in}\frac{R_f}{R_x} = -V_{in}R_f G_x \quad (3)$$

$$V_{out2} = -\frac{1}{T}\int_T V_{out1} \times V_{in} dt = \frac{1}{2}|V_{in}|^2 R_f G_x \quad (4)$$

Since the signal V_{out2} is very sensitive to variation of the exciting signal, the exciting signal is also measured(5) and compensated.

$$V_{out3} = \frac{1}{2}|V_{in}|^2 \quad (5)$$

Fig. 3 is the circuit developed on the research.

Fig. 3 Multi-channel conductance measurement system

2.4 Visualization method

To visualize measured local void profile, bilinear interpolation method is used

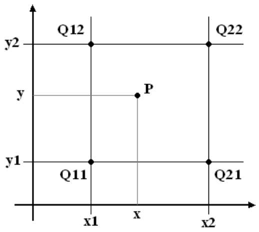


Fig. 4 bilinear interpolation of 2D image

Local void fraction in arbitrary point P in Fig. 4 is reconstructed with the void fraction of surrounding 4 points and its coordinates.

$$f(P) \simeq \frac{1}{\Delta x \Delta y}\begin{bmatrix} x_2 - x & x - x_1 \end{bmatrix}\begin{bmatrix} f(Q_{11}) & f(Q_{12}) \\ f(Q_{21}) & f(Q_{22}) \end{bmatrix}\begin{bmatrix} y_2 - y \\ y - y_1 \end{bmatrix} \quad (6)$$

2.4 Test Facilities

Fig. 5 and Fig. 6 show the experimental facilities for void fraction calibration and two-phase flow.

Fig. 5 Test facilities for void fraction calibration

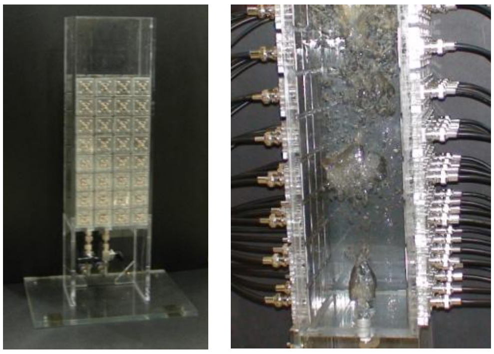


Fig. 6 Test facilities and the experimental two-phase flow

3. Results

Using acryl beads of 6mm, 8mm diameter, a calibration curve of the supposed void fraction and actual void fraction(7) was obtained and it shows that the hypothesis well agrees with experimental data. Fig. 7 is the results.

$$\alpha = 0.676\left(1 - \frac{Gx}{G\max}\right) \quad (7)$$

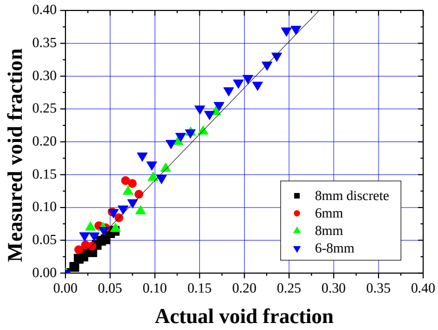


Fig. 7 void fraction calibration result using 6-8mm acryl beads

Fig. 8 is the reconstructed local void profile of Fig. 6. Air is injected from the left nozzle and the free surface of water is initially slight above the top electrodes.

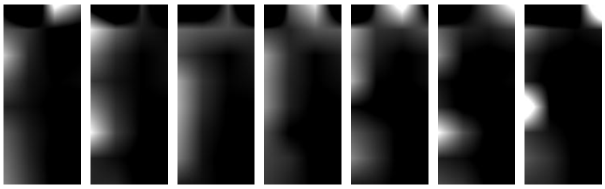


Fig. 8 visualization results of the two-phase flow measurement, 50ms interval

4. Conclusions

A Two-dimensional void profile measurement technique using impedance was developed and verified. Void profile was visualized using bilinear interpolation method. This technique seems to be highly applicable to measure void profile and bubble velocity of two phase flow especially in large slab geometry. This research was applied for the DYNAS 2D slab void profile measurement experiment which was performed in KAERI for thermal hydraulic models verification of the SPACE code development.

REFERENCES

[1] K.M. Bukhari and R.T. Lahey,Jr., An Experimental Study of 2-D Phase Separation Phenomena, Int. J. Multiphase Flow, Vol. 13, No. 3, pp. 387-402, 1987.
[2] C. -H. Song, M. K. Chung, H. Cheon, Measurements of void fraction by an improved multi-channel conductance void meter, Nuclear Engineering and Design Vol. 184, pp. 269–285, 1998.
[3] H.C. Yang, D.K. Kim, M.H. Kim, Void fraction measurement using impedance method, Flow Measurement and Instrumentation Vol. 14, pp. 151–160, 2003.