Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

A Preliminary Design of a Wire Mesh Sensor for Measuring a Void Fraction

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1. Background

Steam explosion phenomena [1] are accompanied with a multi-dimensional and multi-phase fluid flow and heat transfer phenomena. The void fraction is one of the major parameters, which governs the premixing behavior of melt particles in water and the explosion behavior of the pre-mixed fuel. However, efforts for the development of a reliable measurement technique for the void fraction are still underway, as it deals with an interaction between a melt at a very high temperature and water in a short time scale.

Hundreds of conductivity type probes installed in a test section enabled a monitoring the evolution of a melt-water interaction zone in the ECO test [2]. A technique using a dual energy X-ray system was developed to measure the gas fraction, liquid fraction, and melt fraction simultaneously for a small-scale steam explosion experiment [3]. A high-energy X-ray system for monitoring multi-phase fractions is now being developed at CEA [4].

Recently a measurement of multi-phase fractions by using a wire mesh system has been introduced [5]. It has an advantage that the speed of the measurement is fast and a direct measurement is possible.

As a part of a feasibility study for using a wire mesh technique for a steam explosion experiment, this paper discusses the design of the wire mesh and the results of the preliminary calibration tests.

2. Design of a Wire Mesh System

2.1 Measurement principle

Fig.1 shows a schematic view of the wire mesh grids. Two planes of wire grids are placed at a short distance from each other. The angle between the wire girds is 90°.

Pulses of a driving voltage are supplied to the wires of the first plane (transmitter). If the pulse, given to one of the transmitter wires, arrives at a certain wire of the second plane (receiver plane), it is assumed that the crossing point between the two selected wires is occupied by the conducting phase (water). This detection is performed for all the crossing points of the wires of the two planes by means of a multiplexing circuit. In the end, the volumetric water fraction can be obtained by relating the number of crossing points occupied with water to the total number of crossing points.

In the present design, the wire mesh system consists of 16 lines of wires at each plane. The diameter of the wire is 0.25 mm and the distance between the two grid planes is 2 mm. The two layers of wires are installed in a circular frame to be fitted in a circular flow channel.

The distance between the wires is 6 mm. A conceptual picture of the wire mesh is shown in Fig. 1.

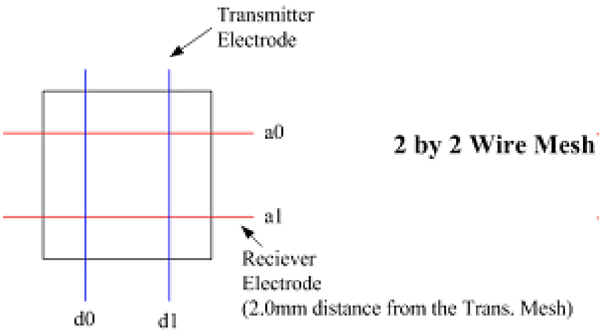

Fig. 1 Conceptual picture of wire mesh

A multi-function board was developed to drive the wire meshes and to perform a signal processing. It consists of a DSP processor, a 16 channel multiplexing 200 KHz A/D converter, a digital I/O for each plane of wires, and a sample and holder for each channel. The system design developed in house is configured into a PC based system.

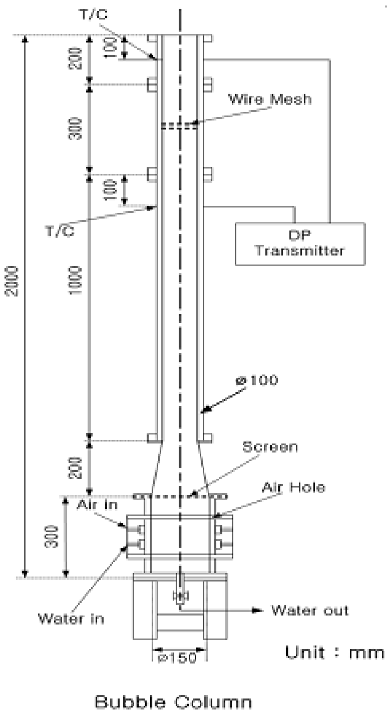

Fig.2 Schematic diagram of the bubble column

2.2 A bubble column for a calibration test

A bubble column having a height of 2000 mm and a diameter of 100 mm is used to perform a calibration test. Fig. 2 shows a schematic diagram of the bubble column.

A bubble generator is installed at the bottom portion of the bubble column. A converging channel follows the bubble generator to enhance the uniform distribution of the bubbles. After the exit of the converging channel, a straight portion of the test section follows, whose height is 1500 mm. A differential pressure gauge is installed between the 1000 mm location and the 1300 mm location to measure the collapsed level, which can be converted to the void fraction.

At first, a voltage signal for a pure liquid phase and a pure gas phase was obtained as reference signals. Fig. 3 shows a typical signal for a pure liquid. Each square wave is a single unit for measuring a void fraction. It consists of eight data points. The total number of signals for this system is 256. As shown in Fig. 3, the shape of the signal is in a sine wave form. It is due to the difference in the length of the wire, as the wires are fitted into a circular frame.

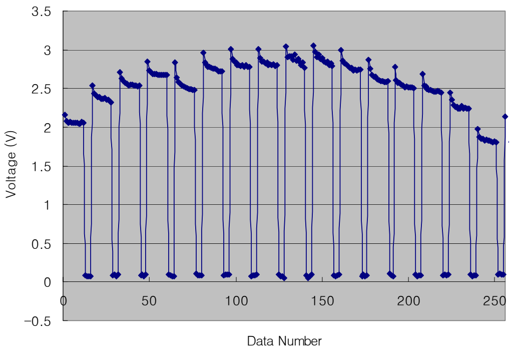

Fig.3 Voltage signal in case of pure liquid

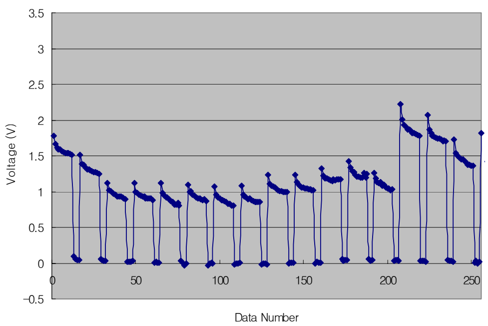

Fig.4 Voltage signal when void fraction ~ 30%

Fig. 4 shows a typical voltage signal when the channel void fraction is about 30%. From each square signal, we can determine the void fraction by using the reference voltages obtained from the cases of a pure liquid phase and a pure gas phase. The measured void fraction was calibrated by using a differential pressure gauge (Model 3051 pressure gauge, Rosemount). It was shown that the void fraction measured by the wire mesh agreed reasonably well with that by the differential pressure gauge in the low void fraction region, while there was a significant error in the case of a high void fraction. The reason for the difference was judged to be due to the slow multiplexing speed. So, it was decided to increase the speed of a multiplexing by upgrading the hardware.

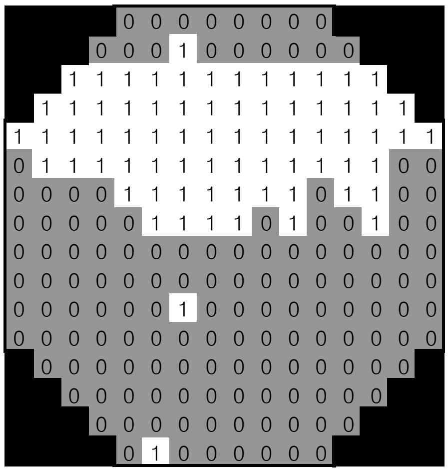

Fig.5 Mapping of void when void fraction ~ 30%

3. Summary and Discussion

The advantage of a wire mesh is a direct measurement characteristic. At a certain time span, each segment of the test section would be either liquid rich or gas rich. Fig. 5 shows a simplified diagram of a test section filled with a two-phase flow. So, the wire mesh has an advantage that it can give us both a void fraction and a direct view of the two phase flow regime. A further investigation will be continued to investigate the effect of a melt phase on the measurement and to find a means for reducing the measurement uncertainties.

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