Proceedings of the Korean Nuclear Society Autumn Meeting
Seoul, Korea, October 1988

Development of a Mesh-Type Computer Tomography for the Two-phase Flow

Jae Young Lee and In Wook Lee
HANDONG UNIVERSITY
School of Mechanical and Metallurgical Engineering
3 Namsong ri Heunghae-eub, Pukku, Pohang,
Kyungbuk, Korea, 791-940 Email: jylee7@han,ac.kr

Abstract

This paper is to describe the development of a mesh-type computer tomography for the two-phase flow. The sensor is made of many parallel wires in the orthogonal orientation . A demultiplexer circuits is developed for electrodes to supply driving voltage and for data acquisition system to get the output voltage form the electrode unit. For the reconstruction of image a direct inversion algorithm is adopted. Full automation is provided from the data sensing to the image construction. Through the careful calibariation and field tests in the horizontal and vertical two-phase loop, the present sensor detect images for the solitary wave and the slug realistically. This sensor could be a useful tool in the laboratory experiments.

1. Introduction

The measurement of two-phase parameters such as the void fraction, the interfacial area concentration, the local velocity profiles is very important because the two-phase interface has complex structure according to the flow conditions. The amount of transport is directly related to this, lot of effort has been made for both modelling and measurement. Recently, tomography sensors start being used to two-phase flow analysis. The conventional tomography intensively used in the medical science has profound experience and high accuracy. But they are not popular because of their high cost and difficulties in mounting to the two-phase flow system. The radiation tomography such as the gamma ray or X-ray needs special shielding system and license. NMR is not chief system at all. Recently, the tomography sensors based on the electromagnetic filed has been developed because of its low cost and weak health hazard. As listed in the table 1, as a token of the low cost, the ECT has a problem of low accuracy around 10% error. Many studies for accuracy has been made in the way of developing more sophisticate algorithms for the image reconstruction and developing the reliable electronic circuits[1,2,3]. The application of the electro computer tomgraphy(ECT) sensor to the process enegineering is now increasing as listed in the table 2. The Impedance type ECT has been used for the water based two-phase flow system. But for the powder flow, the capacitance ECT is better than the Impedance ECT has a merits because of its no need of coverage of electrode with the inside conducting medium.

In this paper, a mesh type tomography sensor is developed for the analysis of the two-phase flow. This sensor is basically intrusive and disturb the fluid flow. But the reconstruction algorithm is very simple and clear so that it could be used for the evaluation of the other ECTs. The byproduct of this development is the electronic circuits for driving it, which could be applied to the other ECTs with minor changes. After brief introducing the structure and working principles of the sensor, the driving electronic circuits and several case study for the its verification will be discussed.

Table 1 Comparison of the various tomography sensors.

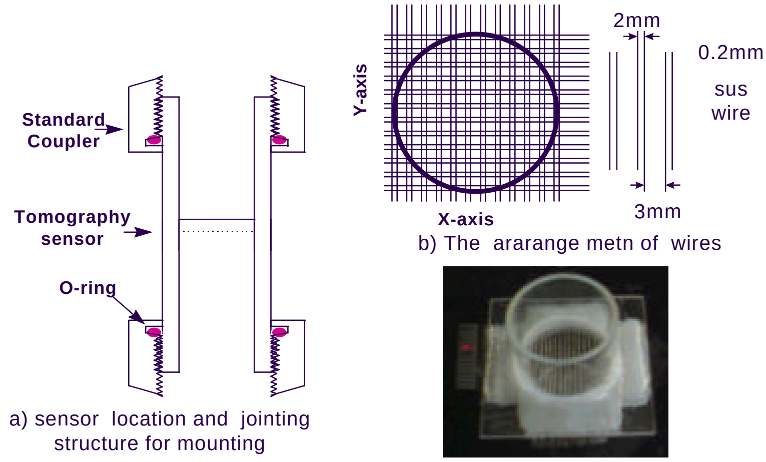
Principles	accuracy	Technology related	Note
Radiation	1%	Optics X-ray & gamma ray positron emission, Nuclear Magnetic resonance	fast, Optical access required slow, radiation confinement leveled particle, not on-line Fast, expensive for large vessel
Acoustic	3%	Ultrasonic wave	sonic speed limitation, complex to use
electric properties	10%	capacitance Conductances Inductance	fast, low cost suitable for small or large vessels

Table 2. The utilization of electric tomography in the process engineering

applications	sensor type	special features	Developers
pneumatic conveyor	capacitance	Measurement of the solid mass flow in the fluidized bed(100frames/sec)	Edwards et al (1995)
Oil field pipeline	capacitance	gas/void fraction (200frames/sec)	Xie et al (1995)
Fluidized bed	Gamma capacitance	Risers and standpipe (less then 1m in diameter), experimental rig with 0.15m in diameter for the gas bubble image	Bernard Et al (1995) Halow(1995)
Tricked Bed	X-ray capacitance	packing Morphology (0.6m in diameter) high speed fluid pulse (0.12 m in diameter)	Toye et al (1995) Reineck (1995)
Hydrocyclones	Resistance X-ray	Distribution and density in the Industrial separator 20MM	William et al(1995) Miller&Lin (1995)
Colloidal suspension	Resistance magnetic resonance	The sedimentation of the debris in the tube of 1mm diameter.	William (1995) Gibbs (1995)
Environmental large scale	Resistance	leakage detection in the Nuclear Waster	Ramirez (1995) Daily (1995)
Mixer	Seismic Resistance	cross hole image multiplane image	Elbring(1995)

2. Design of the Mesh-Type Tomography Sensor

The present tomography sensor is a mesh type which have many thin wires. The structure is simple enough to put many two-parallel wire groups. The parallel two wires has been used for a long time to measure the wave dynamics in the ocean science. Also, it has been successfully used to measure the fine structure in the film flow for the condensation and annular flow in the two-phase flow. The uniform electric filed in between two parallel wire guarantees the proportionality of its resistance to the wetted area in the two parallel wires. The present mesh type tomography sensor is designed by just mounting many two wire sensors in X-direction and Y-direction as shown in FIg. 1. In the present study, the stainless wires of 0,2mm in diameter are used and the distance between wire is 2mm. Improvement in accuracy is expected when wires thickness is reduced and many sensing units are introduced.



a) sensor location and jointing structure for mounting

b) The ararange metn of wires

c) The photographe of the sensor

Fig.1 The schematic descrition of the mesh-type tomography sensor

2.1 Electronic Circuit for driving the tomography sensor

In this studies, an electronic circuit to manage many electorode units in the sensors. The main missions are sequential change of target electorode unit for power supply and data catching from it. Isolation of the other units is also made. The oscillator of the square wave with 2MHz in maximum directs all this sequential activity by triggering demodulators and CMOS switches. For easy expalnation, the circuit system could be divided into 5 parts as shown in Fig.2.

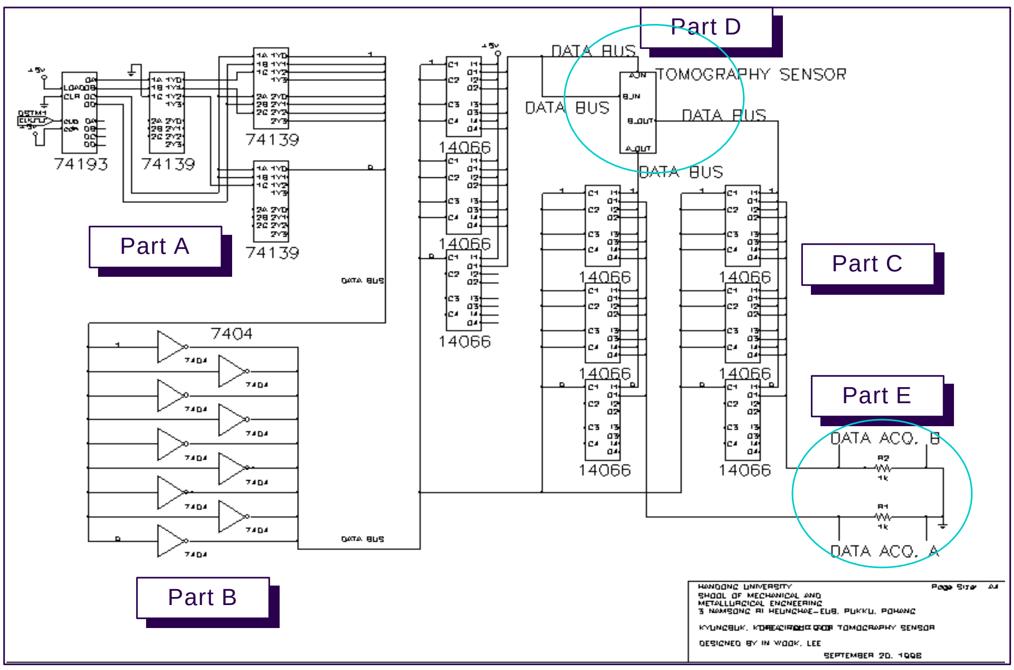


Fig. 2 The electronic circuit for driving the tomography system

In the part A, there is theresettable synchronous up/down binary generator, IC 74153, to count 16 channels connected to the demultiplexer, 74139, to make a switching operation by shifting each gate for the 16 channels. The IC 74239 is the dual two-to-four demultiplexer which selects 4 channels from Y0 to Y4 according to the input signal A and B . The front 74139 determine the enable and disable status for the following two 74139 so that each could shift 8 channels. Since the signal from the part A is a long square wave, an invertor is mounted in the part B which is making a short peak in the signal e wave shape as well as working as a Buffer by generating output voltage. In the part C, CMOS switches are used to remove interference among electrodes. The band of working voltage of CMOS switch is broad from 3V to 13 V. Also it has the fast operation characteritics sue to its short delay in the operation. So the electrode units could get power upto 15 V beacuse of the CMOS switches. Part D is the control bus assmbly connected to the many electrode units (nine units in x-direction and Y -direction each)in the tomography s ensors. In the Part E, the change of resistance in the tomography sensor due to two-phase flow is converted to the voltage by putting the resistance in series, This output voltage from the excited unit is transferred to the Personal Computer through the data acquisition board, ACL1200.

2.2 Image reconstruction

The direct reconstruction method is adopted to generate image of this ECT. Normally, the image reconstruction is a well-known inverse problem. But the possibility of multiple solutions in the inverse problem, it is not easy. To reconstruct tomography form the capacitance ECT and impedance ECT, sophisticate computation of the electric filed distribution and the optimization is made to reduce the error between the measured and calculated value[4,5,6]. But the direct image construction is simple. This direct reconstruction has been used in the X-ray tomography where the beam intensity depending on the scattering due to the internal structure. The variation of the intensity is represented in x-ray image. Only the thing to be considered is the exponential characteristics in the penetration of the radiation through the body:

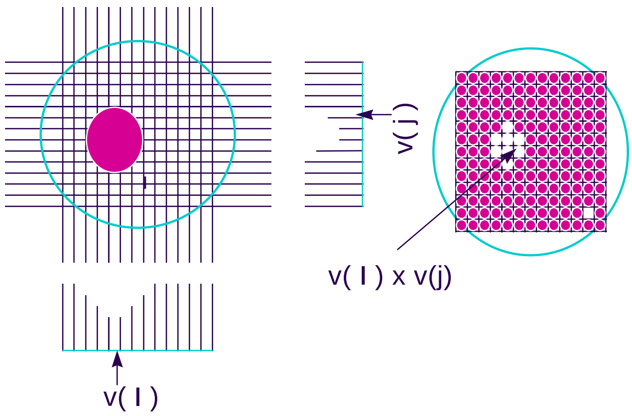


Fig.3 The direct reconstruction of image of the mesh-type tomography sensor

$$I = I_o e^{-\mu x} \qquad (1)$$

From the above equation, tomography image could be obtained by measuring the spatial distribution of the shield parameter μ(x,y). In this case, the determination is made

$$\mu(x,y) = \mu(x) \times \mu(y) \tag{2}$$

where

$$\mu(x) = \frac{\ln\left(\frac{I(x)}{I_0}\right)}{L_x} \quad \text{and} \quad \mu(y) = \frac{\ln\left(\frac{I(y)}{I_0}\right)}{L_y} \tag{3}$$

The intensity of X-ray is proportional to the gray level in the film. The same logic could be made for the mesh type tomography sensor. The intensity of radiation is correspondent to the voltage drop between the electrode. If we have the voltage drop of I electrodes in the x direction and that of j electrode in the y direction, the impedance at where the two electrode cross is proportional to the product of two values:

$$\varepsilon(i,j) = C\ v(i) \cdot v(j) \tag{4}$$

where C is the coefficient.

3. Results and Discussions

In this section, the calibration and field measurement for both horizontal and vertical two-phase loop are presented. The calibration is made to linear dependency between the wetted area and the output voltage. The solitary wave is checked in the horizontal loop. slug flow is observed in the vertical flow loop.

3.1 Calibration

Figure 4 shows the calibration curve. As the sensor is submerging into the water, the impedance of teach electrode is decreasing, the voltage drop between electrode is measured:

$$V = \frac{R_s}{R_s + R_a} V_o \tag{5}$$

where V_o is the supplied voltage, R_s is the impedance of between the sensor electrodes, R_o is the serial resistance attached. Since the uniform electric field is made between two parallel wire, the variation of the resistance of sensor, R_s, is proportional to the wetted area. If we select sufficiently larger resistance, R_0, than the resistance of the sensor, we could obtain the nearly linear calibration curve between the measured voltage and the height. The calibration is made in the way of submerging the sensor assembly to the water and measure the high of the water surface from the bottom of the sensor assembly as shown in Fig. 4. The monotonic increasing calibration curve is made by extracting constant voltage from the measured voltage drop.

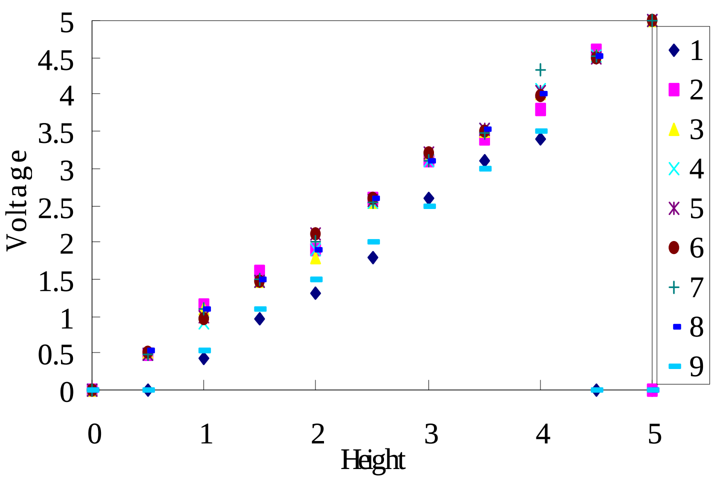


Fig. 4 Calibration curve of the mesh type tomography sensor

3.2 Horizontal Two-phase flow

To measure the two-phase tomographic image from the horizontal channel, a horizontal loop is constructed with a transparent pipe of 5cm in inner diameter and 2 meter in length. The air and water are mixed up in the chamber at the left side as shown in Fig. 5, Also, the air and water are separated at the right end of the channel and the water is accumulated into the storage tank. In this case, a two-wire impedance level meter is mounted the 1/r part of the pipe and the tomography sensor is mounted at 15 cm from the level sensor. The wave propagation is monitored by the front level sensor and the signal at the vertical center electrode in the tomography sensors The signal from the vertical electrode generate the level data the tomography sensor .

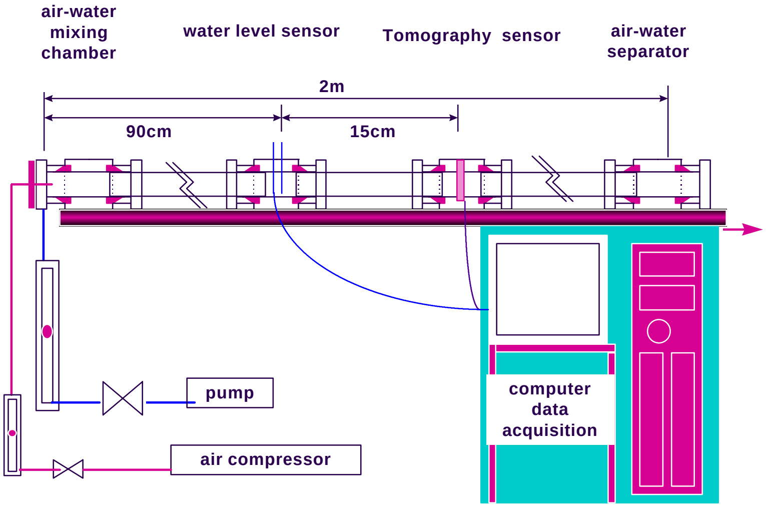
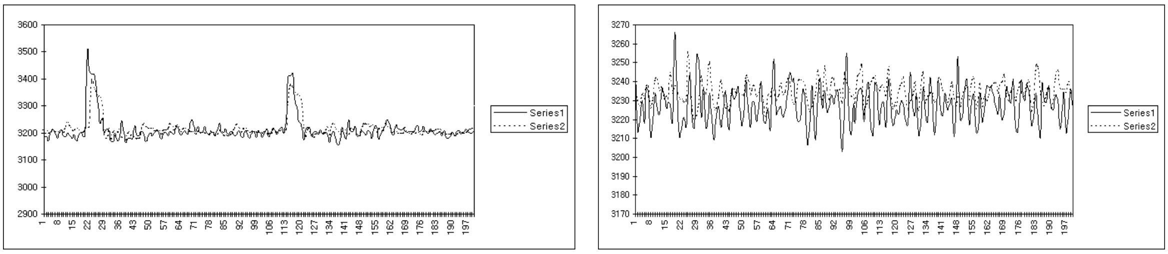


Fig.5 The horizontal loop for the air-water two-phase flow

In Fig. 6, the solitary wave at the high air flow rate and the sinusoidal wave in the low air flow rate are presented which are observed in the horizontal loop. The dotted line is the data form the middle electrode in the tomography sensor which shows the wave propagation. The sampling rate was 1kHz. The tomograph images reconstructed according to the inverse algorithm here are presented in the Fig. 7, In the figure, the white circle means the air and balck circle means the water. The figures are generated in the speed of 1 fram per 10 msec. The solitary wave is observed in the upper left frames and the periodic small waves apperes in the sequential frames.



(a) water :12 lpm -air 55 lpm (b)water 8 lpm-air 15lpm

Fig.6 The time variation of the water level

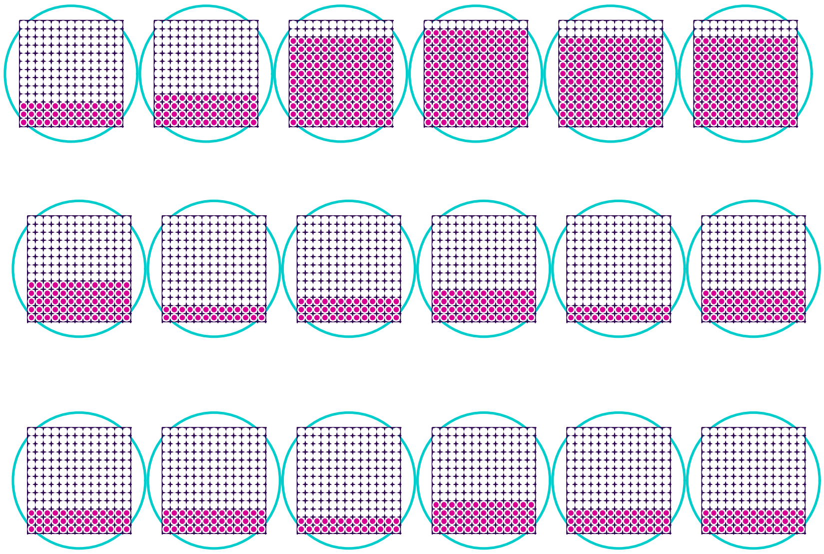


Fig.7 The tomography images for the solitary wavy stratified flow in the horizontal loop (frame/10 msec)

4.3 Vertical two-phase flow

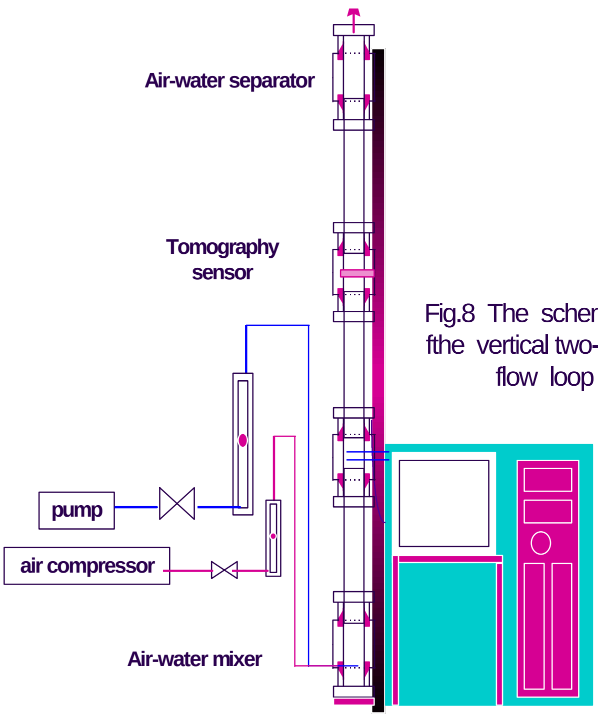


Fig.8 The schematic o fthe vertical two-phase flow loop

As shown in Fig. 8, the mesh type tomography sensor is mounted on to the vertical air-water two-phase flow loop 5cm in diameter and 2 meter in length. The 3 Hp pump inject water to the bottom mixing chamber where the air from the compressor is mixed. The mixed air-water flows upward making a typical bubble pattern. The bubble position is measured by the Tomography sensors as shown in Fig. 9 In Fig. 9, the tomography images obtained each 1 msec for the slug flow are presented. The cap bubble and the following small bubbles are observed well. The present sensor could be used to measure the two-phase structure in the vertical system also.

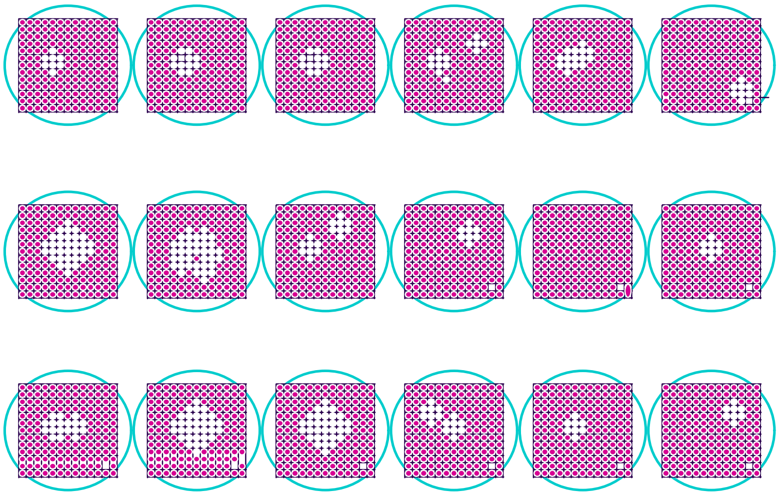


Fig. 9 The tomographic images form the slug flow in the vertical flow loop(frame /10msec)

4. Conclusions

In this study, a mesh type electric computer tomography system is developed. The mesh type intrusive electrode assembly is used to get the local resstance in the two-phase filed. The system has the merits of the simple structure and fast response due to simple reconstruction algorithm. It could be useful for the benchmarking test of the other ECT such as the Imperdance and Capacitance tomography. The developed driving circiuts is working fast upto 2 MHz. Careful calibariation and field test in the horizontal and vertical two-phase loop show that the tomography of the solitary wave and the slug are realistically constructed. This sensor could be a useful tool in the laboratory experiments.

Acknowledgements

This work is supported by the Ministry of the Science and Technology in the program of fundamental Research on Nuclear Engineering.

References

[1] Jae Young Lee, " Development of the Two-Phase Computer Tomography Sensors for the Nuclear Safety Analysis , Final Report for The Fundamental Research on Nuclear Engineering, March 1998. Ministry of Science and Technology,

[2] O.C. Jones et al, " Impedance imaging relative to gas-liquid systems, " Nuclear eng. and desg. 141(1993)159-176

[3] Klung F and Mayinger F 1993, Novel impedence measuring tech for flow composition in multi-phase flows, Proc. 2nd ECAPT Conf.

[4] Xie et al, Electrical capacitance tomography for flow imaging-system model for development of reconstruction algorithm and design of the primary sensor, " IEE Proc. G 139, 89-98

[5] Isaksen, 1993, A new reconstruction algorithm for process tomography Meas. Sct. Tech. 4 1464-75

[6] Huang et al, 1989, Tomographic imaging of two-component flow using capacitance sensors, J.Phys. E, Sci. Ins. 22 173-7