Al-Hinai, Sulaiyam and Lucas, Gary

An Impedance Cross Correlation (ICC) Device For Measuring Solids Velocity And Volume Fraction Profiles In Solid-Water Flows

Original Citation

Al-Hinai, Sulaiyam and Lucas, Gary (2009) An Impedance Cross Correlation (ICC) Device For Measuring Solids Velocity And Volume Fraction Profiles In Solid-Water Flows. In: University of Huddersfield Research Festival, 23rd March - 2nd April 2009, University of Huddersfield. (Unpublished)

An Impedance Cross Correlation (ICC) device for measuring solids velocity and volume fraction profiles in solids-water flows.

Al-Hinai S.M. and Prof. Lucas G.P.

University of Huddersfield

Abstract:

Multiphase flow is the simultaneous flow of two or more phases, in direct contact, in a given system. It is important in many fields of chemical and process engineering and in the oil industry, e.g. in production wells and in sub-sea pipelines. The behavior of the flow will depend on the properties of the constituents, the flows and the geometry of the system.

Upward inclined solids-liquid flows are sometimes encountered in the process industries for example in water treatment processes and in oil well drilling operations. Measurements of the local solids volume fraction distribution and the local axial solid velocity distribution are important, for example, in measuring the solids volumetric flow rate.

This study presents a non-intrusive Impedance Cross-Correlation (ICC) device to measure the local solids volume fraction distribution and the local axial solids velocity distribution in upward inclined solids-water flows in which these distributions are highly non-uniform.

The ICC device comprises a non-conductive pipe section of 80mm internal diameter fitted with two arrays of electrodes at planes, A and B, separated by an axial distance of 50mm. At each plane, eight electrodes are equispaced over the internal circumference of the pipe. A control system consisting of a microcontroller and analogue switches is used such that, for planes A and B, any of the eight electrodes can be configured as an 'excitation electrode' (V^+), a 'virtual earth measurement electrode' (ve) or an 'earth electrode' (E) so that different regions of the flow cross section can be interrogated. Conductance signals from planes A and B are then cross correlated to yield the solids velocity in the region of flow under interrogation.

Experiments were carried out in water-solids flows in a flow loop with an 80 mm inner diameter, 1.68m long Perspex test section which was inclined at 30° to the vertical. The most significant experimental result is that, at the upper side of the inclined pipe, the measured solids velocity is positive (i.e. in the upward direction), whilst at the lower side of the inclined pipe the measured local axial solids velocity is negative (i.e. in the downward direction). This shows quantitative agreement with previous work carried out using intrusive local probes to measure the solids velocity profile. The study also shows qualitative agreement with high speed film of the flow.

It is believed that this method of velocity profile measurement is much simpler to implement than dual-plane electrical resistance tomography (ERT).

Research Aims and Objectives:

The aim of this study is to measure the solids velocity and solids volume fractions in an inclined flow in each part of the pipe at a certain flow condition.

This aim is achieved by meeting the following objectives:

- ✓To design an Impedance Cross-Correlation flow meter with two axially separated electrode arrays.
- ✓To design a conductivity circuit to measure the mean velocity of the dispersed flow.
- ✓To design a switching circuit for the impedance cross-correlation flow meter controlling by computer through the LABJACK.
- ✓To investigate the sensitivity distribution in the ICC flow meter cross section area associated with given electrode configurations in a static bench test.
- ✓To develop an Impedance Cross-Correlation flow meter model in FEMLAB (COMSOL) to simulate the static bench test experiments.
- ✓Compare the determined results in both bench tests experiment results with simulation results and analyse the error.
- ✓To install the ICC flow meter device in inclined pipe 30º in a real flow loop using an inclined pipe configuration and measure the solids velocity profiles and the solids volume fraction profiles in each part of the pipe of the dispersed phase. This was done by using the electrode selection mechanism for both electrode arrays. This means that eight electrode configurations were used i.e. pipe divided into eight parts, figure (1). The electrode configurations were set by taking each electrode with its consecutive electrode (i.e. 1&2, 2&3 … 8&1) as excitation and virtual earth measurement and the rest are set to earth.

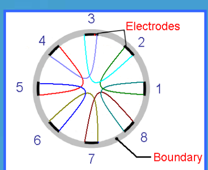
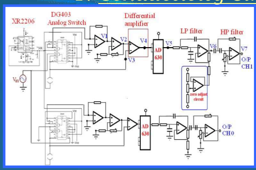


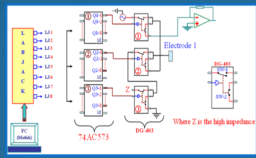
Figure 1: Single array of 8 electrode

Designs and Experimental setup:

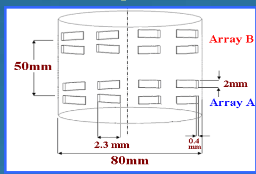
1. Conductivity Circuit design



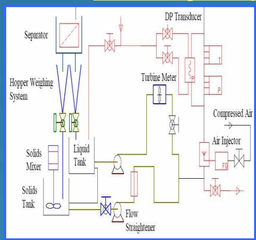
2. Electrode selection switch



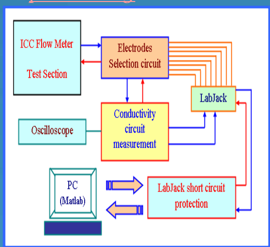
3. Impedance Cross-correlation flow meter

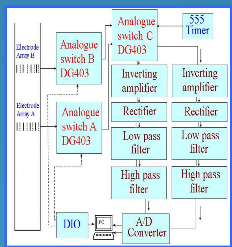


4. The Multiphase flow loop



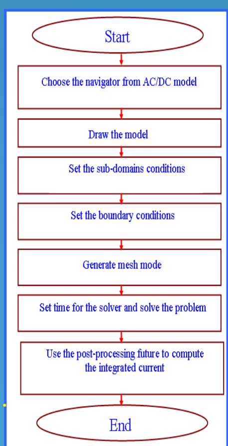
Data acquisition & control system and data processing

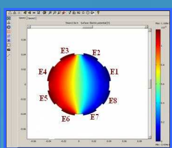


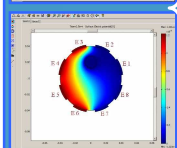


ICC device modelling using FEMLAB

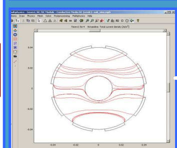
➢FEMLAB flowchart







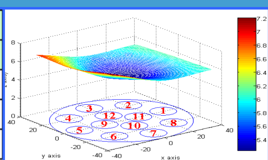
Effect on the potential distribution of inserting a simulated nylon rod



Effect on the current flow of inserting a simulated nylon rod

Modeling Result

Electrode configuration	Config-1
	Electrode number
Excitation (V^+)	3,4,5,6
Virtual Earth (ve)	1,2,7,8
Earth (E)	none



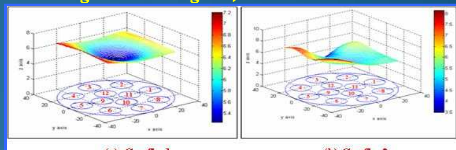
It is clear from Figure above that the system sensitivity in the vicinity of electrodes (3,4,5,6) is much higher than elsewhere in the cross section. However, the lowest sensitivity was at the middle of the pipe. Nevertheless, the sensitivity distribution for configuration 1 is relatively uniform in the flow cross section.

Bench experimental work results:

A series of static bench tests was performed to investigate spatial variations in the sensitivity of the electric 'sensing' field for different electrode configurations. These tests will enable us (at a later stage when the device is used in pipe flows) to know which electrode configuration is most suitable for interrogating a particular part of the flow cross section.

Electrode configuration	Config-1	Config-2
	Electrode number	Electrode number
Excitation (V^+)	3,4,5,6	4,5,6
Virtual Earth (ve)	1,2,7,8	1,2,7,8
Earth (E)	none	3

The system sensitivity for configurations 1 and 2 are shown in figure (a),(b). The vertical axis in figure (a), (b) represents the sensitivity parameter (also represented by the colour scale to the right of the diagram).

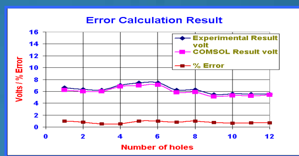


(a) Config-1 (b) Config-2

It is clear from Figure (a) that for configuration 1 the system sensitivity in the vicinity of electrodes (3,4,5,6) is somewhat higher than the sensitivity in the vicinity of electrodes (1,2,7,8). The lowest sensitivity was at the middle of the pipe. Nevertheless, the sensitivity distribution for configuration 1 is relatively uniform in the flow cross section.

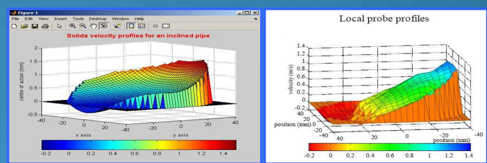
Figure (b) shows the sensitivity distribution for configuration 2. In the vicinity of electrodes (4, 5, 6) the sensitivity is high compared with the sensitivity in the vicinity of electrodes (1,2,7,8). However, the sensitivity in the vicinity of electrode (3) was low. This is due to the fact that (3) is a grounded electrode.

Comparison in sensitivity distribution between modelling and static test results



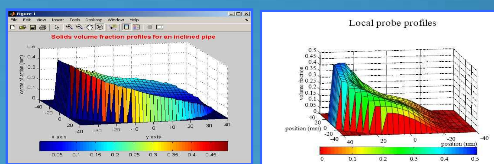
Flow loop and comparison

1. Solids velocity profiles at 30º inclined pipe (QW=12.22m3h-1, QS=0.994m3h-1)



The most significant aspect of the data shown in the figures above is that, whereas at the upper side of the inclined pipe the solids velocity is positive (i.e. in the upward direction), at the lower side of the inclined pipe the local axial solids velocity is negative (i.e. in the downward direction). ***[Note that the figure in the right hand side was produced from the local probe, where figure in the left hand side from the present work.]***

2. Solids volume fraction profiles at 30º inclined pipe (Q_W=12.22m^{3}h^{-1}, Q_S=0.994m^{3}h^{-1})



The figures above shows the local solids volume fraction distribution in an upward solids-in-water flow in an 80mm i.d. pipe inclined at 30° to the vertical. It is clear that the solids particles preferentially accumulate at the lower side of the inclined pipe. ***[Note that the figure in the right hand side was produced from the local probe, where figure in the left hand side from the present work.]***

Conclusions:

1. Static test

- The aim was to alter the electrode configurations at array A and B to measure conductivity variations in localized regions of the two planes.
- The area of the flow cross section 'interrogated ' by the ICC device has been shown to be highly dependent upon the electrode configuration.

2. Modelling

- A successful computational single-array model of the ICC device was achieved.

3. Flow loop test

- The obtained data successfully showed good agreement with similar tests carried out using local conductance probes.