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Extended Abstract

Improving the Accuracy of Oilfield Multiphase Flowmeters by understanding Flow Structure

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1 INTRODUCTION

Electrical Capacitance Tomography (ECT) has been used over a number of years to measure flow structure in gas-liquid flows. Such flows are widespread in the oil and gas industry and understanding them and measuring concentrations, velocities and mass flowrates is a vital part of oilwell and oilfield monitoring. Existing multi-phase flowmeters (MPFMs) often use cross-correlation techniques to measure in-situ transit velocity of flow structures.

Bubble structures in two-phase oil-gas flows have been measured using a twin-plane ECT system. Measurements are presented showing that the flow of gas and liquid in a pipe exhibits many and varied structures, often wavelike in form in common with other free surface flows. Because of the restriction of the pipe surface surrounding the flow, the waves are bound to this circular geometry and form structures that from the outside of the pipe may appear visually to fill it, but non-intrusive imaging shows otherwise. Understanding the bubble structure and its evolution along the pipe is essential in interpreting cross-correlation measurements in multiphase flowmetering, and is an essential step in realising lower uncertainty of measurement for oilfield MPFMs.

2 ECT OPERATION AND APPLICATION

Electrical capacitance tomography (ECT) is a non-intrusive technique that can be used for imaging and velocity measurement in flows of mixtures of two non-conducting materials. Developments over the last 15 years have made fast, accurate measurement systems available for laboratory research giving accurate images [1]. Using ECT can offer measurements unobtainable with other measurement technologies, but the interpretation of quantitative flow data requires a good physical model of the interaction of the materials with the electric field in the sensor and appropriate reconstruction and analysis algorithms.

Cross-correlation between the image planes gives the velocity distribution across the flow. The resolution of ECT images is limited, so cross-correlation is not carried out for all pixels, but for a set of larger 'zones' containing the average of a number of pixels.

3 EXPERIMENTAL SETUP AND RESULTS

The experimental results presented here compare a simple short 0.08m internal diameter pipe section, with a clamp-on external ECT sensor as shown in Figure 1 with results from a 0.067m id pipe 6m long reported [2]. In the first case air was injected through a side port about 1m below the sensor to generate a single bubble filling the pipe followed by a distributed bubbly flow for a short time. This is a classic 'Taylor' bubble. In the second case the flows varied from dispersed bubbly through Taylor bubble and churn to annular.

Optically the Taylor bubble fills the pipe, but it can be seen from the image in Figure 1 that the bubble is off-centre, something common in larger diameter pipes. Previous work [1] has shown that ECT images are generally accurate in these types of flow.

Fig. 1 – Commercial ECT System

Figure 2 shows the average electrical permittivity against time for the same Taylor bubble, with data taken from two planes of electrodes about 6cm apart. It is quite apparent that the time difference between the planes can be used to measure transit velocity of the structure.

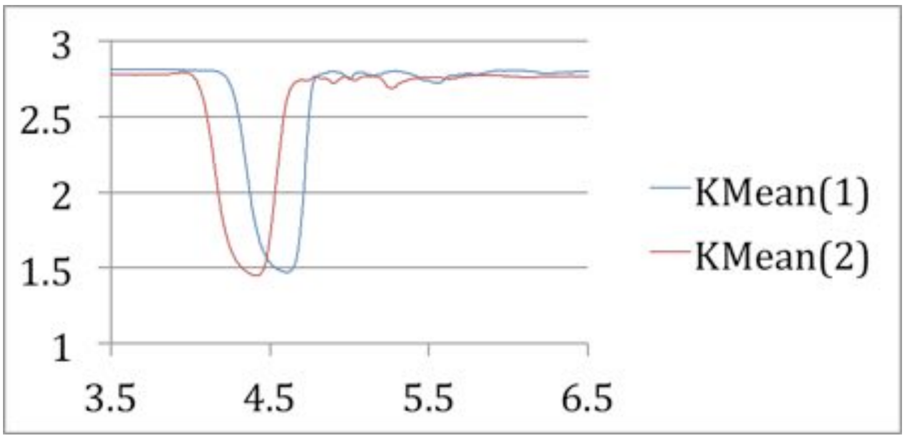

Figure 2. Permittivity against time in seconds for two planes of ECT separated by 6 cm.

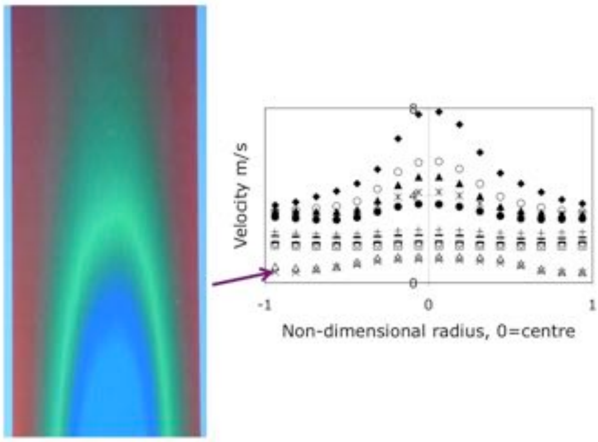

Figure 3 (a)

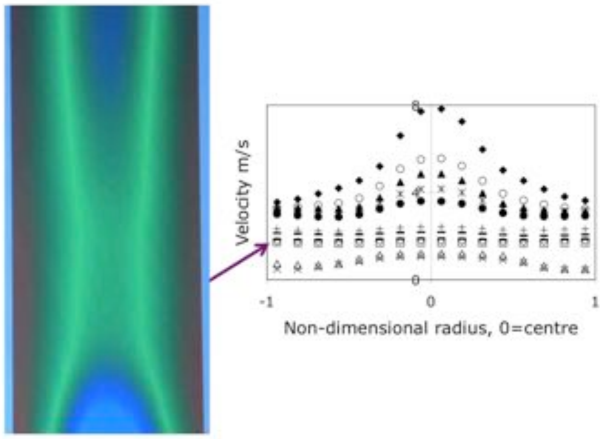

Figure 3(b)

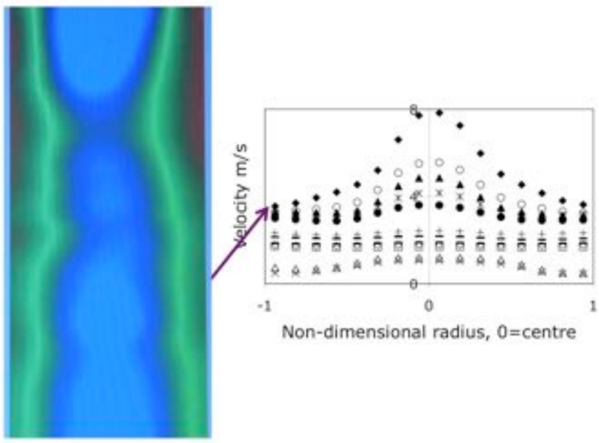

Figure 3(c)

Figure 3. Left hand side shows vertical cross-section ECT image, right-hand side shows velocity distribution for that flow from [2].

Referring now to results from the longer pipe at higher flowrates, as reported in [2], Figure 3 shows three conditions where the correlation velocity can be identified with different flow structures. Fig 3a shows similar large Taylor bubble to Figure 1, the velocity profile is centre-peaked. Figure 3b shows a churn-Taylor bubble transition where the velocity profile is essentially constant across the flow, while Figure 3c shows an intermittent wave structure alternating with annular gas-core flow which is consistent with the pictures of huge waves shown in [3] and where the velocity profiles are now strongly centre-peaked.

4 CONCLUSIONS

Bubble structures in two-phase oil-gas flows have been measured using a twin-plane ECT system. Measurements are presented showing that the flow of gas and liquid in a pipe exhibits many and varied structures, often wavelike in form in common with other free surface flows. Because of the restriction of the pipe surface surrounding the flow, the waves are bound to this circular geometry and form structures that from the outside of the pipe may appear visually to fill it, but non-intrusive imaging shows otherwise. Understanding the bubble structure and its evolution along the pipe is essential in interpreting cross-correlation measurements in multiphase flowmetering, and is an essential step in realising lower uncertainty of measurement for oilfield MPFMs.

5 REFERENCES

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