Application Note

Process Tomography Flow

Introduction

Flow processes may involve a variety of phases or components in the gas, liquid or solid phase and are complex in their nature. Electrical tomography techniques provide the capability for flow visualisation, regardless of material opacity, to enhance the understanding of such complex flow processes.

Solid-liquid Flow

CSIRO (Melbourne, Australia) required a measurement technique to measure the particle and fluid properties in solid-liquid flows for both research and industrial application. Electrical Resistance Tomography (ERT) met the criteria due to the robust and simple nature of the equipment and the absence of any radioactive, cryogens or dangerous components means the equipment can be readily employed at mine sites both above and below ground. Measurements were performed on a 100 mm diameter flow loop with closely graded 2 mm silica sand suspended in clear shear thinning polymer suspensions. These 'model' suspensions mimic the behaviour of bimodal suspensions of particles containing a large fraction of fine rheologically active particles that would form a non-Newtonian carrier in which would be suspended the coarser fractions such as those found on mining co-disposal lines.

Figure 1 shows a comparison between a photograph of the actual pipe flow and ERT derived concentration maps using on-line single step Linear Back Projection (LBP) algorithm and off-line iterative Sensitivity Conjugate Gradients (SCG) algorithm. The LBP algorithm has the advantage that images are produced on-line at rates of multiple images per second. However, it can be seen that there is some blurring of the solid-liquid interface. The SCG algorithm is in substantial agreement with actual pipe flow conditions.

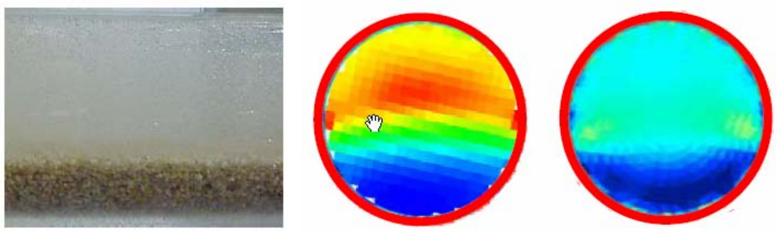

Figure 1: Comparison between actual pipe flow and ERT derived concentration maps

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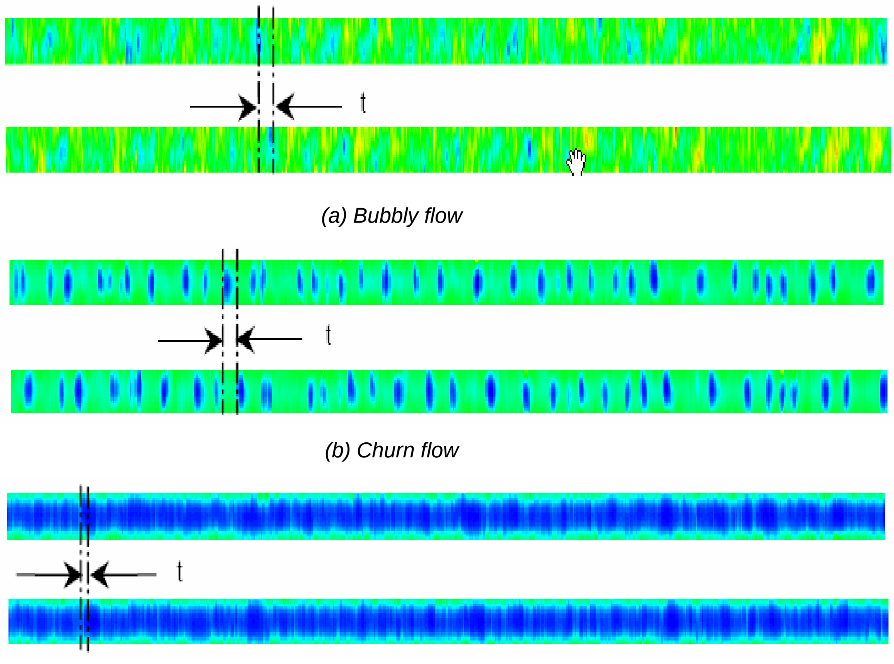
Gas-liquid Flow

Researchers at the University of Leeds (UK) and the Chinese Academy of Science have used ERT to study gas-liquid flow regimes and their transitions. An ITS p2000 ERT system coupled to a dual-plane sensor was used to image the flow characteristics and cross-correlation was performed to interpret the cross-sectional velocity distribution of the gas phase. Figure 2 shows a time series of vertical slices through the cross-sectional conductivity tomographic images obtained for bubbly, churn and annular flow for the two measurement planes (P1 & P2). P2 is located a short distance downstream of P1. A colour scale is used to represent conductivity with green corresponding to water and increasing gas concentrations indicated by yellow and blue. The dashed black line shows how features of the flow may be correlated from P1 to P2.

By applying the cross-correlation technique on a pixel by pixel basis the cross-sectional gas-phase velocity between P1 and P2 can be determined as shown by the result for bubbly flow in Figure 3.



(a) Bubbly flow

(b) Churn flow

(c) Annular flow

Figure 2: Time series of a vertical slice through the cross-sectional conductivity tomographic images for three flow conditions

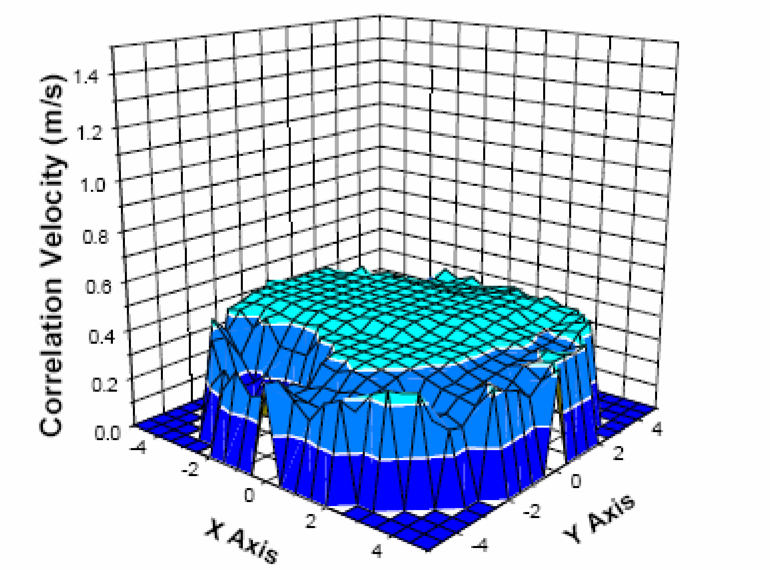


Figure 3: Cross-sectional gas-phase velocity for gas-liquid bubbly flow

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Liquid-liquid Flow

In July 2007 ITS performed a study on an oil-water flow loop at University College London using the p2000 ERT system. Measurements were performed for a range of flow conditions and with particular emphasis on conditions causing phase inversion. Figure 3 shows sample tomographic images displaying the cross-sectional conductivity distribution for stratified oil-water flow at oil concentrations of 40, 50 and 60%. Blue indicates zero conductivity and hence the oil phase whereas red corresponds to the conductivity of the water phase.

Figure 5 shows a plot of the mean image conductivity over time for a bubbly flow of oil in water as the oil content in the flow was gradually increased. As the oil concentration increases there is a decrease in conductivity. At the moment of phase inversion, the conductivity drops to zero as oil becomes the continuous phase.

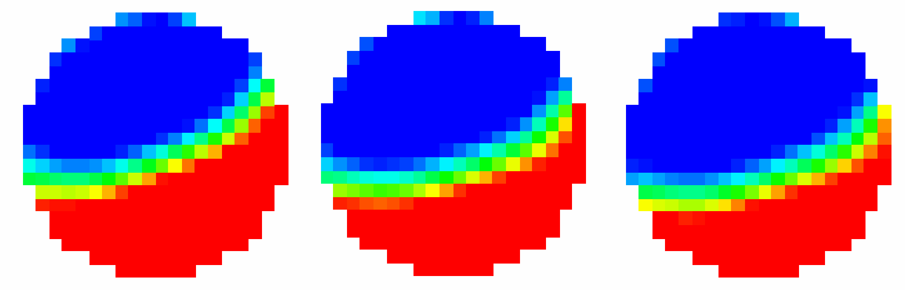

Figure 4: Cross-sectional conductivity tomographic images for 40, 50 and 60% oil.

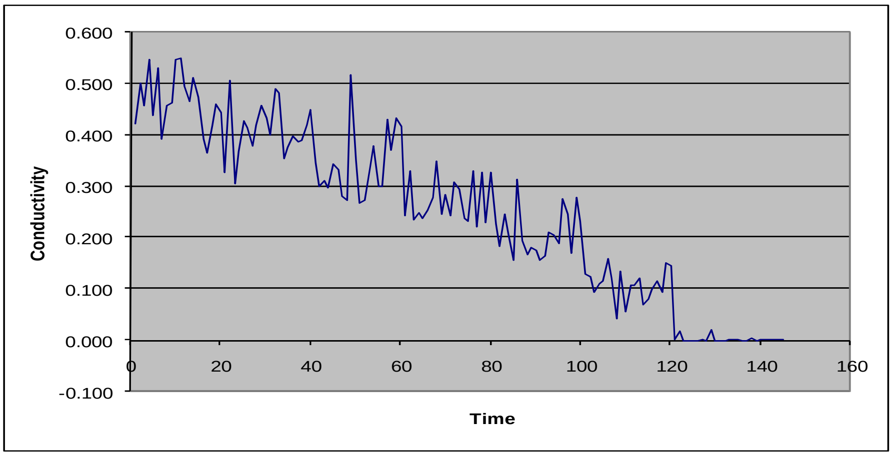

Figure 5: Mean image conductivity as oil content is increased

Customer Benefits

The application of electrical tomographic measurement techniques to flow processes has been widely demonstrated. The benefits to the user are:

1. Improved process understanding allowing optimisation of computational models
2. Increased confidence when designing flow systems with capital cost savings
3. Reduced energy consumption

Further Reading

Graham L, Hamilton R, Rudman M, Strode P and Pullum L (2002) Coarse solids concentration profiles in laminar pipe flow, Hydrotransport 15, Banff, Canada, June 2002

Wu, Y., Li, H., Wang, M. and Williams, R.A. (2005) A study on the characterisation of air-water two-phase vertical flow using electrical resistance imaging, 3rd World Congress on Industrial Process Tomography, Banff, Canada, 2-5 September 2003

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