See **inside** your process

Flow

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 or dangerous components meant the equipment can be readily employed at mining 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.

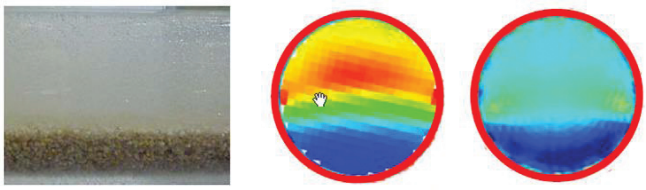


Figure 1: Comparison between actual pipe flow and ERT derived concentration maps using on-line single step Linear Back Projection (LBP) algorithm and off-line iterative Sensitivity Conjugate Gradients (SCG) algorithm.

Figure 2: Cross-sectional conductivity tomographic images for 40, 50 and 60% oil.

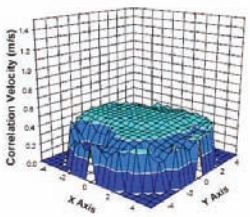
Liquid-liquid Flow

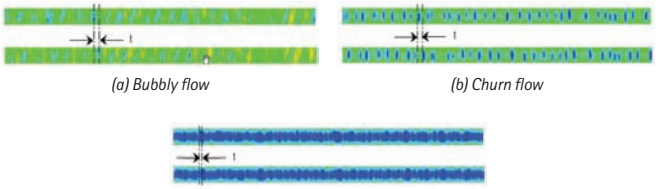
In July 2007 ITS performed a study on an oil-water flow loop at University College London using the p2000 ERT system. Measurements were performed for a range of flow conditions and with particular emphasis on conditions causing phase inversion. Figure 2 shows sample tomographic images displaying the crosssectional conductivity distribution for stratified oil-water flow at oil concentrations of 40, 50 and 60%. Blue indicates zero conductivity of the oil phase whereas red corresponds to the conductivity of the water phase.

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





(a) Bubbly flow *(b) Churn flow*

(c) Annular flow

Figure 4: Time series of a vertical slice through the cross-sectional conductivity tomographic images for three flow conditions

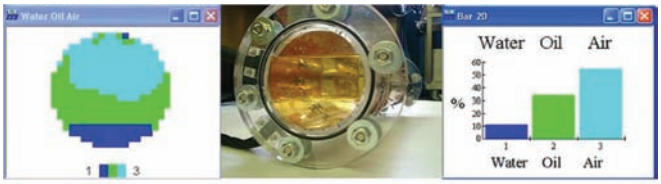


Figure 5: Images taken from ITS software showing combined modalities of ERT and ECT data

Three-Phase Flow

ITS has combined multiple modalities of resistance and capacitance tomography. Resistance tomography provides data on water/oil-gas components and capacitance provides data on water-oil/gas components. By taking data contemporaneously, full three phase flow information can be provided in certain flow regimes, such as stratified air/oil/water shown here.

Key Benefits

Improved process understanding allowing optimisation of computational models

Increased confidence when designing flow systems with capital cost savings

Reduced energy consumption

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See **inside** your process

Case Study: Multiphase Flow

The Challenge

Polimeri, a subsidiary of Eni SpA, sought a measurement system capable of multiphase flow visualisation in a pilot scale flow loop at their Novara Research Centre in Italy. The primary goal was to enhance understanding of multi-phase flows comprising oil-water-gas for the optimisation of existing mathematical models of hydraulic transportation processes.

The Solution

The ITS m3000 dual-modality Electrical Resistance Tomography (ERT) and Electrical Capacitance Tomography (ECT) system has been developed to do on-line monitoring of multi-phase flow by providing detailed information such as multi-phase flow pattern, flow regime, composition and velocity. The m3000 ERT and ECT modules produce conductivity and permittivity maps from multi-electrode sensors arranged around the pipe.

The Polimeri flow loop consists of a feed tank (which also acts as a liquid-gas separator), pump, 2" diameter pipe and a gas injection system. It is instrumented with temperature sensors, pressure transducers and viscometers.

Experiments were conducted on water-gas and oil-gas systems for a range of flow conditions. Measurements were collected at a rate of 20 Hz. The operating conditions in terms of the gas and liquid superficial velocities (VG and VL) are shown in the table to the side of the figure.

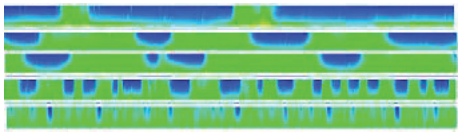

Figure 1: Water-gas flow data

V_G ms^{-1}	V_L ms^{-1}
3	0.2
0.3	0.2
0.07	0.2
0.07	0.3
0.07	1.0

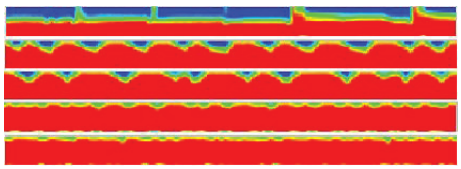

Figure 2: Oil-gas flow data

V_G ms^{-1}	V_L ms^{-1}
3	0.2
0.3	0.2
0.07	0.2
0.07	0.3
0.07	1.0

In addition to visualising the flow regime Polimeri were interested in measuring the composition of the multi-phase mixtures. Further experiments were performed for the oil-gas system using the m3000 ECT module with a high-speed digital video camera for comparison. The m3000 system is calibrated with the pipe senor full of gas and full of oil. A linear relationship is used to determine the concentration of oil-gas mixtures. Image analysis software was used to determine the composition from the high-speed video camera data independently from the m3000.

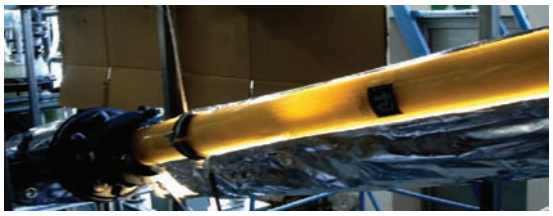

Figure 3: Inclined flow loop

Figure 4: Oil-Gas flow

Good agreement between the m3000 and high-speed video camera were obtained for the composition measurements thus paving the way for electrical tomography to be used to measure the composition of multi-phase flows. Electrical tomography has the benefit that it does not require optical access as a high-speed video camera does.

The ITS m3000 dual-modality electrical tomography system has been successfully applied to multi-phase flows by Polimeri. The combination of ERT and ECT allows the full range of flow conditions to be explored from 100% water to 100% oil and intermediate conditions.

Customer Benefits

Optimisation of existing mathematical models of transportation processes

Greater confidence when sizing pipes and reactors with capital cost savings

Increased plant yields and capacity

References

Qiu, C, Bagatin, R, Palmery, S, Bolton, GT, On- line visualization of asymmetric multi-phase flow in an industrial flow loop applying multi-modality process tomography system, 5th World Congress on Industrial Process Tomography, 3-6 September 2007, Bergen, Norway

Wu, Y., Li, H., Wang, M. and Williams, R.A. (2005) Characterisation of air-water two-phase vertical flow using electrical resistance imaging, The Canadian Journal of Chemical Engineering, Vol. 83, February 2005

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