

Non-intrusive Measurement of Volume and Mass using Electrical Capacitance Tomography

Andrew Hunt¹, John Pendleton² and Malcolm Byars³

Electrical capacitance tomography (ECT) has been used for some years to measure the concentration distribution within multiphase flows and processes. ECT is a relatively low resolution measurement, but it has many advantages, including being non-intrusive, fast and relatively inexpensive in comparison to other techniques. Recent developments of twin-plane systems have enabled measurements to be made of velocity as well as concentration. We have developed techniques to establish from these measurements the volume, mass and velocity of flow structures in two-component flows, and in particular the mass and velocity of large individual particles and groups of particles in solids/gas flow systems.

ECT measurements are made by placing rings of electrodes around the circumference of the pipe or vessel of interest, measuring the electrical capacitance between each independent pairing of electrodes and using image reconstruction techniques to show the permittivity distribution within the sensor. Typical arrangements have between 6 and 12 electrodes placed evenly on the circumference, with 5 rings of electrodes along the axial length – a total of between 30 and 60 electrodes each a few centimetres long. Usually rings 1, 3 and 5 are linked as guard electrodes, while rings 2 and 4 are the measurement sets. We have recently developed ECT systems that can make measurements at up to 300 complete frames of data per second for 6-electrode twin-plane systems. A large range of sensor shapes and sizes may be fabricated but the most common are circular in cross section with diameters ranging from a few cm to some 10's of cm.

In two-component systems, permittivity maps may be interpreted as concentration distributions, and the sensor is calibrated to give values between 0 (full of the low-permittivity material) and 1 (full of the high-permittivity material). The images are usually plotted on an arbitrary 32*32 grid of pixels and are of use in interpreting instantaneous and average flow distributions. By cross-correlating pixels or groups of pixels between one plane and a second axially separated plane, transit times and hence velocities can be measured. These measurements are effectively being taken as spatial averages over cylinders or cones along the sensor.

At 200 to 300 fps, the measurements have a good resolution for velocities up to 10m/s. By integrating over specified time periods around flow structures of interest it is possible to measure the volume of individual large particles or clusters of particles. By calibrating mass per unit length of the sensor, these measurements may be expressed directly as particle or cluster mass. Results are presented in the paper for simple gravity-drop flows of partly-filled plastic spheres, plastic beads, and also for the conveying of granular material in a pilot plant. We show that resolution of mass to within a few grams is possible on objects of individual mass of between 2g and 35g. We also show measurements of flow structure masses in horizontal and vertical pipes of approximately 50mm diameter, over a range of solids flowrates from 200 to 900 kg/hr and at velocities between 1m/s and 5m/s. General comparisons are made with high-speed video photography of some of the flows, and in the case of gravity-drop flows the accuracy of the mass measurement is established using weighing over fixed time periods.

^{1,2} Tomoflow Ltd., West Hembury Farm, Askerswell, Dorchester DT2 9EN, UK. www.tomoflow.com

³ Process Tomography Ltd., 86 Water Lane, Wilmslow, Cheshire SK9 5BB, UK. www.tomography.com