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Quantitative Measurements Using Electrical Impedance Tomography

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The phases in a multiphase flow often have contrasting electrical properties, and this has been exploited to measure phase distributions and other features of multiphase flows. Often, probes must be inserted into the domain of the flow, which can significantly influence the measurement region. Ideally, measurements would be taken at the domain boundary so as not to disturb the flow, but the measurement would take place over a significant portion of the entire flow domain. Electrical Impedance Tomography (EIT) is a process whereby multiple electrical impedance measurements at the boundary of a multiphase flow are used to reconstruct the impedance distribution within the domain. If the electrical impedance of the domain in mainly resistive, the method is often called Electrical Resistive Tomography (ERT). Multiphase flows with an aqueous continuous phase often can be measured with ERT. When the material impedance is primarily capacitive, the process is often referred to as Electrical Capacitive Tomography (ECT) or Capacitive Imaging Tomography (CIT). ECT has been used to study flows where the continuous phase is a gas, for example.

In EIT, a number of electrodes are mounted to the surface of a domain of interest. Current injections and voltage measurements will be performed at a finite number of locations on the boundary, and these measurements may be averaged over a portion of the boundary surface. The resolution of the reconstructed conductivity field will be strongly related to the number of locations used to probe the domain. To reconstruct the image of the domain, a candidate representation of the impedance distribution in the domain is first constructed, and a set of predicted EIT projections are compared with the measured projections. The candidate distribution is modified until a minimum difference is achieved between the measured and predicted projections. Yet, EIT reconstruction is an inherently ill-posed problem. As such, the reconstructed impedance distribution may not satisfy requirements of existence, uniqueness, or continuous dependence of the solution on the problem data. Most importantly, the EIT solution is sensitive to noise in the projections and the number and geometry of the boundary electrodes.

EIT has been implemented for a variety of multiphase flows, including stratified gas-liquid flow, bubbly flows, liquid-solid flows, gas-solid flows, and three-phase flows. In many instances, the reconstructed phase distributions are qualitatively similar to the expected distributions, but quantitative validation of EIT is more problematic. Over the last few years, we have been implementing both ERT and ECT systems to determine the phase distributions in liquid-gas and gas-solid disperse multiphase flows. Our goal has been to determine the accuracy of the reconstructed phase distribution profiles derived solely from EIT. We have used parallel Gamma Densitometry Tomography (GDT) measurements of the phase distributions to validate the different EIT measurements. An example of the reconstructed solids and void fraction distributions are shown below. In this talk, we will discuss the underlying assumptions of EIT measurement and reconstruction and how they influence the precision and uncertainty of the reconstructed phase distributions. Examples from liquid-gas flows in a bubble column reactor and gas-solid flows in a gas-solid circulating fluidized bed will be discussed.

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