SCALING OF ELECTRICAL RESISTANCE TOMOGRAPHY DATA OF SWIRLED LIQUID-GAS SEPARATION USING FAST CAMERA IMAGING

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Most of the processes in the chemical industry involve the application of multiphase flows. Various types of media are transported in different forms, and thus there is a constant need to monitor online different parameters such as flow conditions, mixing efficiency, phase velocities, and separation parameters [1]. In recent years, swirling flows got popularity for the gas-liquid separation [2]. The principle of separation is based upon the density difference of the phases that separate due to centrifugal forces [3]. The CAD sketch of the inline swirl element used in this research is shown in Figure 1a.

(a) (b)

Figure 1: (a) CAD of the Inline Swirl Element, (b) flow facility during water-gas separation operation showing the swirl and the ERT sensor on the pipe section.

Multiphase flow meters are widely used in the process industry, but they have certain drawbacks such as accuracy, cost, temperature restrictions, stability, and need for calibrations [4][5]. Research on process tomography as a non-intrusive method for multiphase flow measurements has been carried out since the last few decades, primarily due to the higher measurement speed, low implementation cost, and straightforward implementation [6].

The goal of this work is to evaluate the Electrical Resistance Tomography measurement in terms of accuracy when evaluating gas-liquid flow distribution for controlled separation purposes. Figure 1b shows an exemplar picture of the separation flow facility in Lodz (in reality, the pipe section is vertical), where the swirl element and the ERT sensor are installed.

First, to calibrate the system, static tests in tap water were done by placing the hollow phantoms of size ranging from 10mm-40mm in the center of a single plane 16 electrode sensor. The camera images and ERT data were recorded in the same configuration. The 2D tomographic images were obtained using the Gauss-Netwon image reconstruction algorithm, as shown in Figure 2. These generally overestimate the real size. Therefore, a scaling approach needs to be found to compute the void fractions as correctly as possible.

(a) (b)

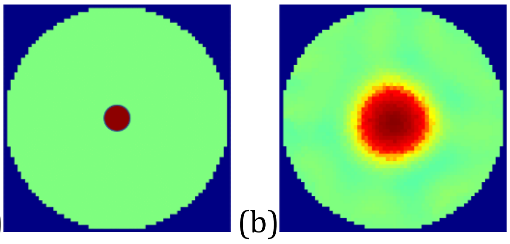
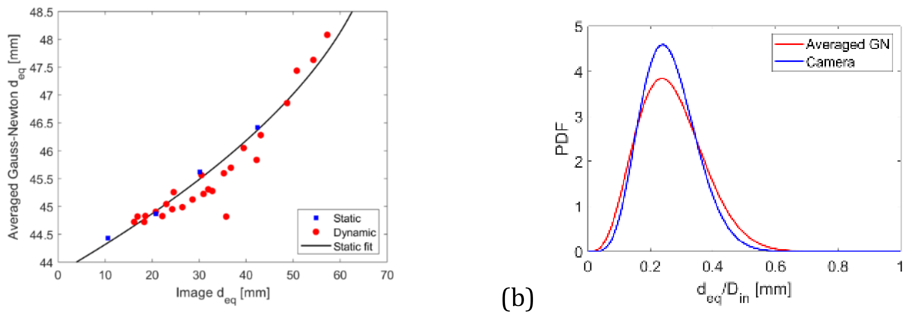


Figure 2: Static Image reconstruction case: (a)10mm phantom in the middle of the sensor. (b) GN image reconstruction

Twenty-five experimental points for tap water and air mixture were chosen to study the gas core evaluation based on the ERT sensor (acquisition rate: 12 Hz) and the fast camera (acquisition rate: 50 Hz). A scattergram of the averaged data points over the 20s of data acquisition of the ERT and camera dynamic measurements for these experimental conditions is shown in Figure 3a. In this figure, A quadratic curve was chosen to fit the evolution of the ERT average void fraction as a function of the camera values in the static case, given by:

$$d_{camera} = -1.511\, d_{ERT}^2 + 152.8\, d_{ERT} - 3794\ (R^2 = 0.9914) \qquad (1)$$

One can notice that the experimental points lie pretty close to the static points and their corresponding fitting curve. This suggests that the scaling of the size retrieved from the ERT measurement is possible. The measurement time series was also performed by analyzing the Probability Density Functions (PDFs) of the camera and ERT signals, as shown for one experimental point in Figure 3b.



(a) (b)

Figure 3. (a) Average equivalent diameters obtained using the Gauss-NewtonGN reconstruction scheme plotted against the camera values for the static and dynamic experimental points. (b) PDF of the equivalent core diameter -to- pipe inner diameter ratio for 1 experimental point.

Both distributions are very close in Figure 3b, even if the PDF of the ERT measurement is usually broader for most of the experimental points. The discrepancy between the PDFs may be caused by the gas core instability during the data acquisition window, continuously losing symmetry and breaking into bursts of bubbles. This causes false data for both modalities. Despite this challenge, the proposed method reduced the ERT error of dynamic measurements of the gas core size from over 300% to below 20%, making it a realistic sensing technique for controlled separation processes.

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