Supporting Information

The PIV technique uses a high definition camera to capture the images, which are treated and then processed the velocity data. For this purpose it is necessary to determine how much photos are needed to capture the flow field. Figure 1 shows the liquid axial velocity for different number of photos. As the bubbles concentrations are higher for the highest gas superficial velocity, the photo tests were performed with 7cm/s.

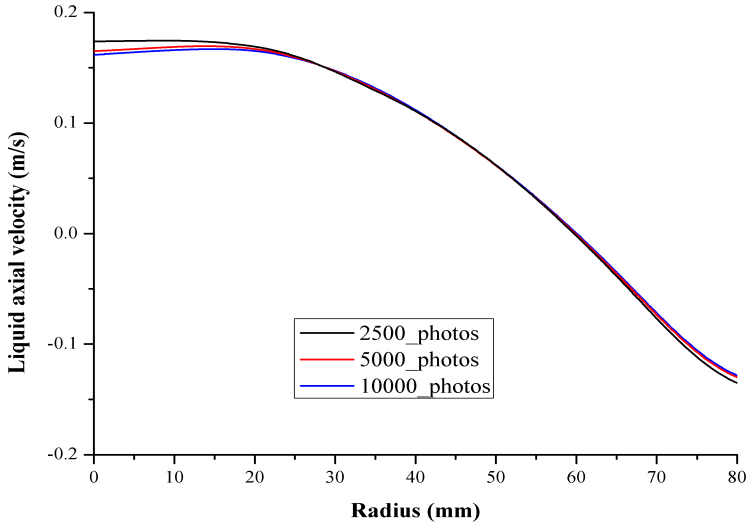

Figure 1: Number of photos

As shown in Figure 1 even 5,000 as 10,000 photos show the same profile, thus it was taken 5,000 photos for all the experiments.

The errors calculations were made according to Kline and McClintock (1958), with a confidence of 95%.

For a single sample, Equation (1) was applied:

$$P_{\bar{x}} = tS_{\bar{x}} = \frac{tS_x}{\sqrt{N}} \qquad (1)$$

where: t for this case was 4.303 (degrees of freedom of 2), S_x is the standard deviation and N is the number of individual readings.

For the Reynolds stress tensors, which are calculated from the experimental data, the error was calculated according to Equation (2).

$$\pm F = \left(\frac{dF}{dx_1}\right)^2 (\varepsilon_1)^2 + \left(\frac{dF}{dx_2}\right)^2 (\varepsilon_2)^2 \qquad (2)$$

In general, if n measurements x_n are being made, each with a measurement tolerance of ε_n, and a function F is calculated using the measured values, then the uncertainty or tolerance in the calculation is determined by Equation (2) (Kline and McClintock, 1953).

In Figures 2 to 4 above, it is shown the experimental triplicate. It can be seen that even with the column division, the liquid axial mean velocities profiles are in accordance at the column center.

The velocity vectors for the three superficial velocities measured are presented in Figures 5 to 7, and the comparison with the numerical result is shown in Figure 8.

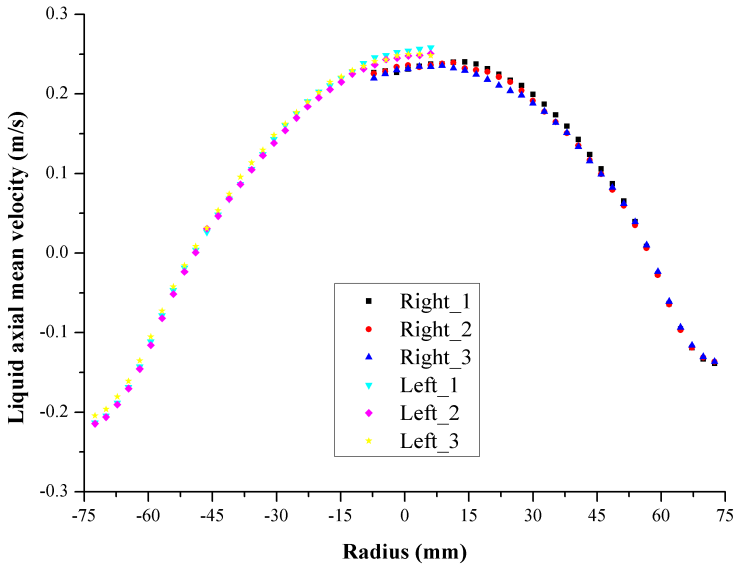

Figure 2: Liquid axial mean velocity - U_{sup} = 3cm/s

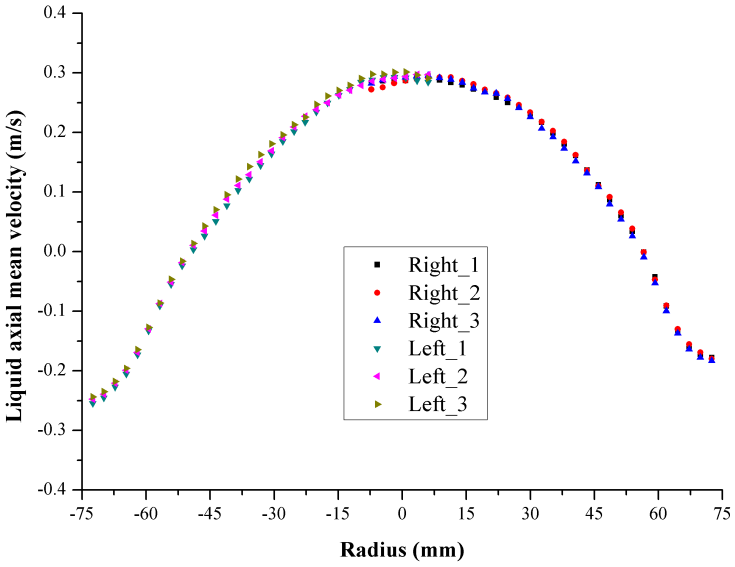

Figure 3: Liquid axial mean velocity - U_{sup} = 5cm/s

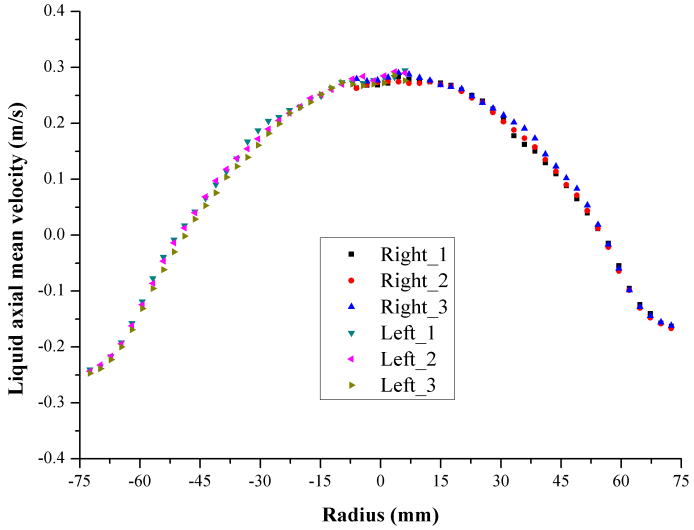

Figure 4: Liquid axial mean velocity - U_{sup} = 7cm/s

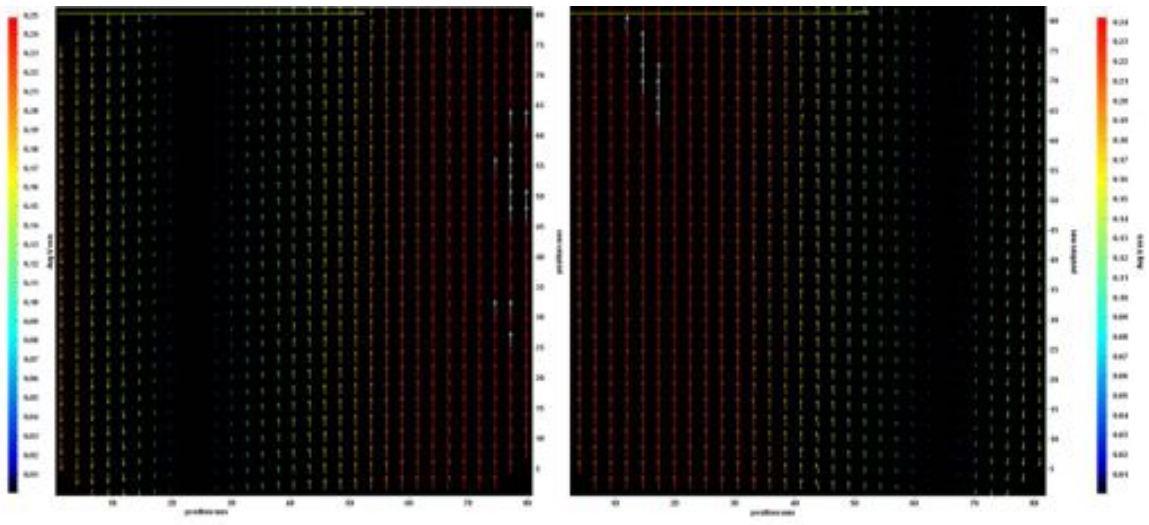

Figure 5: Velocity field (a) right (b) left - U_{sup} = 3cm/s

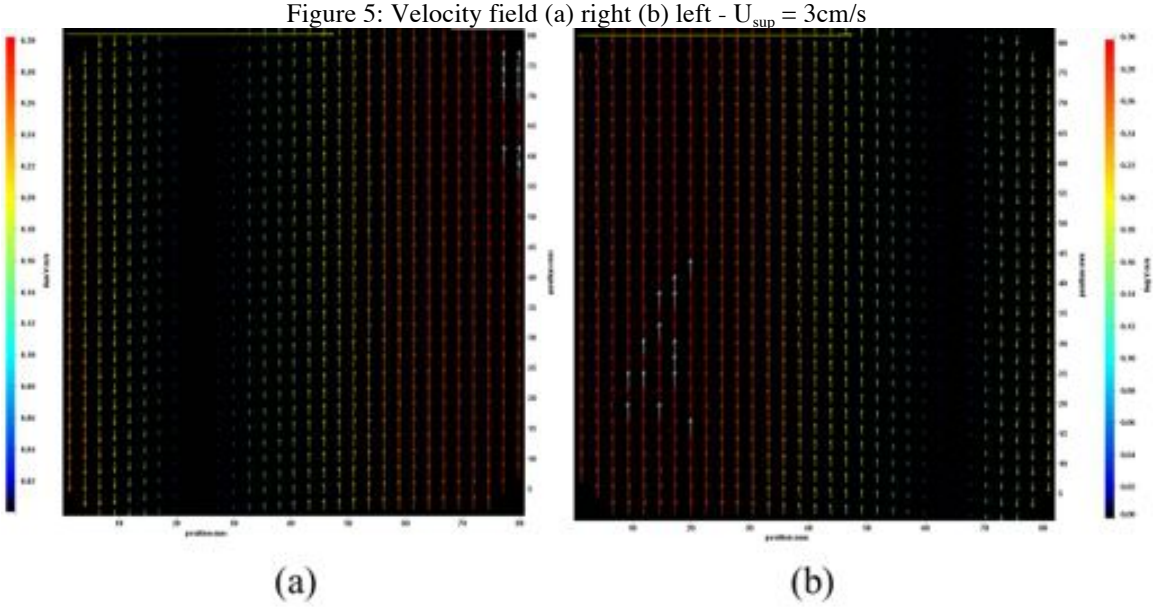

Figure 6: Velocity field (a) right (b) left - U_{sup} = 5cm/s

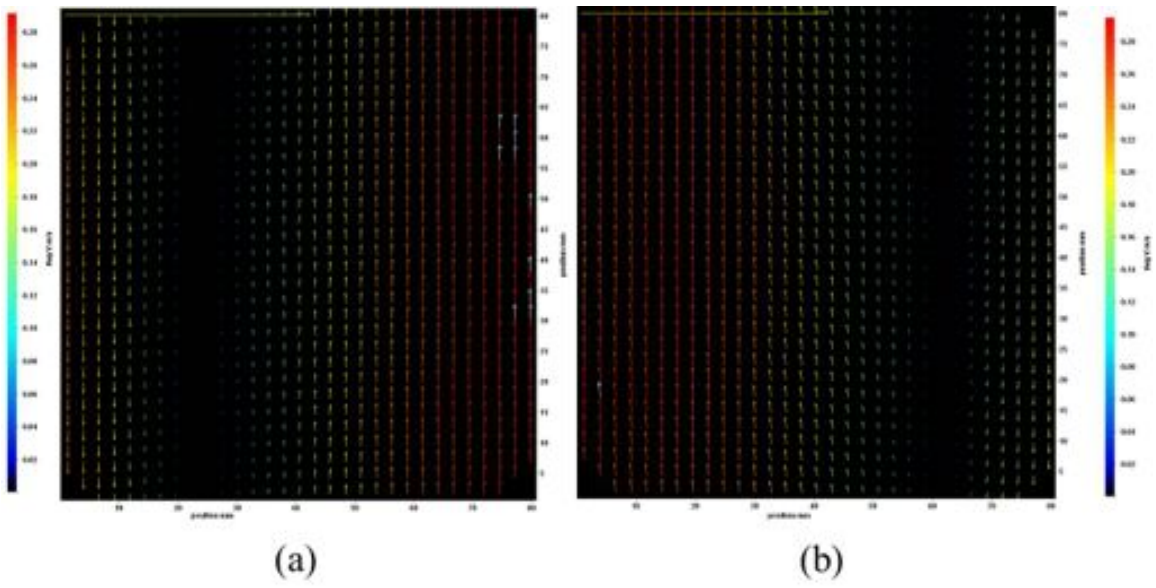

Figure 7: Velocity field (a) right (b) left - U_{sup} = 7cm/s

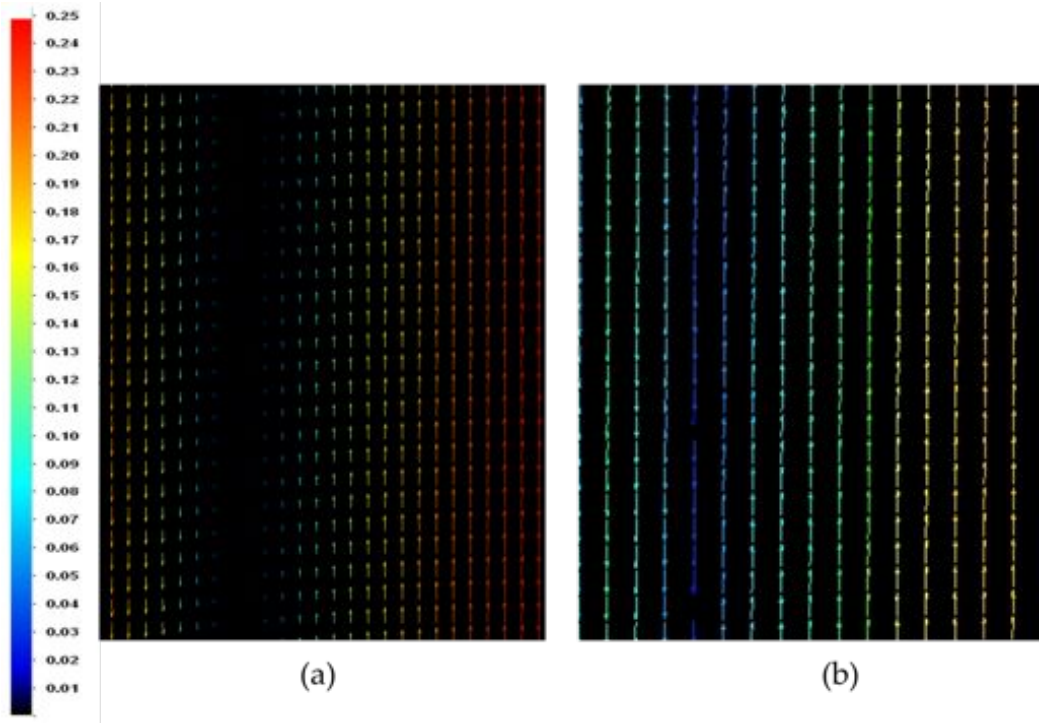

Figure 8: Velocity vectors – (a) experimental (b) numerical

Mesh tests were performed at the same conditions, gas superficial velocity of 7cm/s, Ishii-Zuber drag model and k-epsilon turbulence model. In Figure 9 it can be seen that for all the mesh tested, a similar profile of the liquid axial mean velocity was obtained, thus it was chosen the 100,000 control volumes mesh to perform all the simulations.

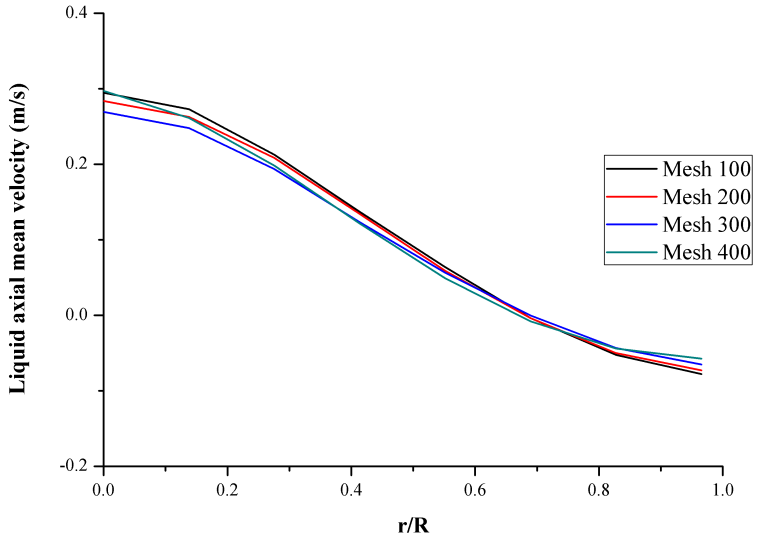

Figure 9: Mesh test

References

Kline, S. J. and McClintock, F. A. "Describing Uncertainties in Single Sample Experiments", vol 75, p. 3-8, 1953.