AN EXPERIMENTAL STUDY ON UPWARD AIR-WATER FLOW IN A VERTICAL PIPE USING LOCAL MEASUREMENT TECHNIQUES: AN EXPERIMENTAL DATABASE

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Summary A steady-state upward isothermal co-current air-water flow in a vertical pipe has been experimental investigated. The facility used in this work is a loop with a measure section with a vertical pipe of 52 mm inner diameter and 6.5m length. Local measurements of void fraction, interfacial area concentration, interfacial velocity and chord length were measured using four-sensor conductivity probes. Liquid velocity and turbulence intensity were measured using LDA. Liquid flow rate was ranged from 0.5- 3 m/s and a void fraction up to 30 %, at atmospheric pressure. 15 radial position at three axial positions were measured by four-sensor conductivity probe. The conductivity probes have been designed by the researchers, and a new algorithm has been developed to process the experimental data. The consistency of these data, with a high resolution in space and time, was thoroughly checked, which makes them suitable for the development and validation of CFD codes.

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INTRODUCTION

One of the most important key issues in the two-phase flow analysis is the existence of multidimensional interfaces between both phases. The correct behaviour prediction of these interfaces, and its quantification is one of the frontiers in the theoretical and experimental studies of this kind of flow, and up to now, there is not an effective technique and methodology for the multidimensional interface characterization in two-phase flow measurement. Then, experimental works play a very important role in the development of new theoretical models and measurement devices.

The basic structure of a two-phase flow can be characterized by three fundamental parameters. These are the void fraction, the Sauter mean diameter (for bubbly flow mainly) and the interfacial area concentration (IAC) . The void fraction expresses the phase distribution and it is a required parameter for the hydrodynamic and thermal design in various industrial processes. On the other hand, the interfacial area describes the available area for the interfacial transfer of mass, momentum and energy, and it is a required parameter for a two-fluid model formulation, and the key for most of the industrial applications. Various transfer mechanisms between phases depend on the two-phase interfacial structures. Therefore, an accurate knowledge of these parameters is necessary for any two-phase flow analyses.

The non-intrusive methods to measure those parameters have a limited use due to the void fraction range limitation, high cost or deficient spatial and temporal resolution. The intrusive method, like needle probes, is a well-established method for the investigation of multiphase flows. Different measuring techniques can be employed for the needle probes. The most known techniques are based on conductivity, capacitance or optical measurements. Based on the phase identification, these probes can provide information about void fraction, IAC, bubble size, frequency, and velocity using simple physical principles. The probes, based on optical or conductivity, are extensively employed for intrusive local measurement. Both probe typologies are very similar and they can share the same signal processing methodology with minor changes.

In the present paper a four-sensor conductivity probe design is used. Local interfacial area concentration, void fraction, interfacial velocity and Sauter mean diameter for air-liquid bubbly flow through a vertical pipe are experimentally studied. The time-average profiles over the radial direction of the test section are presented for liquid superficial velocities in the range [0.5 – 3] m/s, and in each superficial velocity different superficial gas velocities are investigated, with void fraction averages in the range 0 – 25%.

EXPERIMENTAL FACILITY

Figure 1 shows the outline of the experimental facility used to perform the experimental work. It is a thermo-hydraulic loop, with a test section, a lower plenum where air and water are mixed, and an upper plenum where the air is separated from the liquid. The test section is a round transparent tube made out of Plexiglas® with constant section, the inner diameter is 52 mm and the length of the section is 6500 mm. We use purified water as a working fluid, and it circulates due to two centrifugal pumps controlled by a frequency controller and a automatized valve. The air is supplied by an air compressor and it is introduced to the test section through a porous sinter element with an average pore size of 10 mm installed below the mix chamber at the lower plenum. The air and water temperature is kept constant during the test assay by a cooling coil submerged in the tank. The pressure was measured by a pressure sensor at each port of measurement in test section.

A four-sensor probe based on electrical impedance has been utilised as a phase identifier. The model developed at Universitat Jaume I consist of four sensors made of copper wires insulated with varnish. The vertical distance between the front tip and rear sensors was about 2 mm, related to acquire frequency and velocity of the flux in each experiment, in order to achieve required precision. Figure 2 shows a magnified photo of sensing part of the probe. Researcher team has developed a signal processing software using Matlab platform to obtain the main two-phase flow magnitudes, like void fraction, interfacial velocity or IAC using the methodology for four-sensor probe proposed by X. Shen et al. [1].

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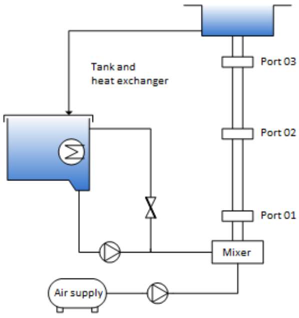

Figure 1. Experimental Facility scheme.

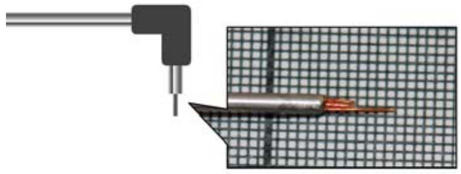

Figure 2   Four-sensors conductivity probe

EXPERIMENTAL DATA AND CONCLUSIONS

Several experiments were done , jf = 0.5, 1 2 and 3 m/s and in each of those cases, runs for different superficial gas velocities were performed. For each run, average profiles were performed at 3 axial positions for each magnitude. Figure 3a,b,d,e show an example of that profiles for each axial position. For each l radial point tan statistical analysis of each parameter was done. Figure 3 c and 3 e shows the distributions for the chord length and velocity measured

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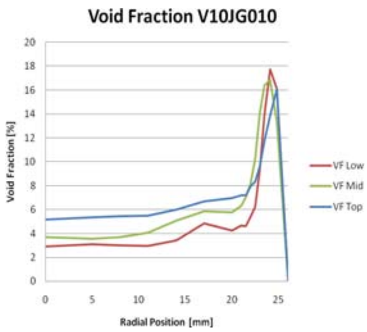
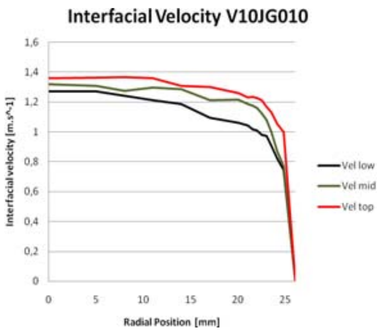
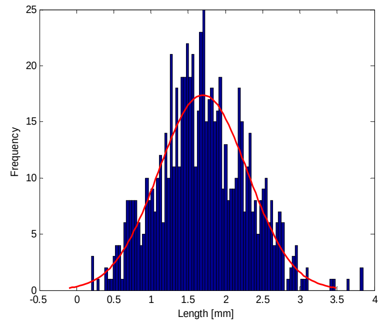


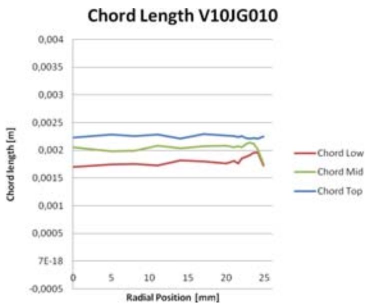
a) Void fraction average profile



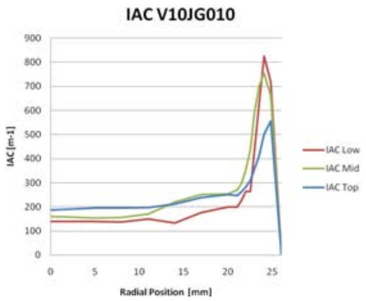
b) Interfacial Velocity average profile



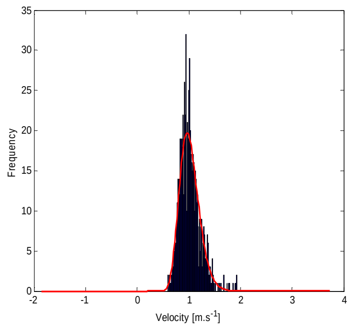
c) Chord length distribution



d) Chord length average profile



e) IAC average profile



d) Interfacial Velocity distribution

Figure 3. Average radial profiles of measured magnitudes at each axial position for a jf =   1 m/s and a 10% void fraction average. Figure c and d, and examples of the magnitude distribution in a measurement point

The data base obtained matches quid well with the published results [2] , but the detailed and spatial resolution obtained in the work could be an excellent tool for model developers and for benchmarking in the CFD codes assessments.

References

[1] Xiuzhong Shen et al.: *Methodological improvement of an intrusive four-sensor probe for multi-dimensional two-phase flow measurement. International Journal of multiphase Flow*: 31 (2005) 593-617

[2] Mendez, Santos. *Medida Experimental de la Concentración de Area Interfacial* , PhD Thesis, Politechnic University of Valencia, Spain, (2008)