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Metrological characterization of multiphase flows using optical techniques

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Abstract: The multiphase flow measurement is a very complex task, and different technologies are used for measurement, but there is a lot to be studied in order to assess the respective reliability. With this aim, the present work shows an analysis of the air-water flow pattern characteristics inside a circular tube, when the measurements are performed using the optical technique shadow sizer. The uncertainty in measurement of gas bubble lengths was estimate, and it was found the occurrence of a repeated sequence of different air bubble characteristics after a two-phase flow pattern was established. It was found low level of uncertainty in measurement when the shadow sizer technique was used.

Keywords: flow pattern map, metrology, experimental methods and uncertainty.

1. INTRODUCTION

In oil and gas production industry, as well as environmental area, the indispensability of multiphase flow [1] measurement with reliability has been evident. Flowmeters manufacturers and oil production companies have been developing technologies for multiphase flow metering, and in some cases such technologies have been commercially available. As new multiphase meters technologies are being increased, the development of reliable procedures for evaluating them is demanded. However, the performance evaluation of these meters is not trivial, because the complex flow characteristics can affect the meter response and also the system where the flow occurs. For metrology area, actually, it is a challenge issue.

In order to promote an improvement of the basis for understanding specificities for measuring multiphase flow, at the National Institute of Metrology, Quality and Technology-Inmetro, this subject has been studied in the Fluid Dynamics Metrology Division - Dinam. For this, it was constructed a bench with horizontal hydraulic circuit for two phase flow (water and air) generation. At this bench, optical techniques, as shadow sizer and particle image velocimetry, are employed for measurement and visualization of the resulting flow patterns inside the pipe.

In this work, the focus is the two-phase flow characterization by using the shadow sizer technique [2], followed by evaluation of uncertainty of the measurements [4] of the gas bubbles length in the flow pattern. The bubble length was measured on the images of the flow. The images were captured through the cameras of the optical system.

It is intended that this work motivates more researchers to be interested in analyzing complex flows under metrological point of view.

2. MEASUREMENT TECHNIQUES AND FACILITIES

2.1. Apparatus

After assembling the horizontal bench, two-phase flow patterns were generated. Simultaneously, parameters of the available bench operational resources were controlled, in order to guarantee repeatability of the flow, which was necessary requisite for carrying out the experimental tests.

The experiments were performed in closed circuit, with test section (circular) made of acrylic with two nominal diameters (25 mm and 50 mm). Excepting the test section, all other parts of the bench were constructed in PVC.

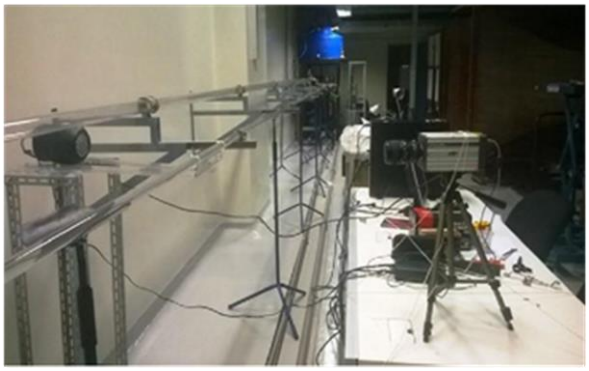


Figure 1 General view of the experimental apparatus.

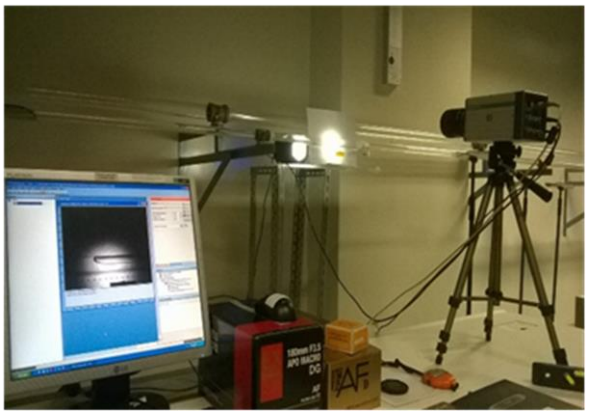


Figure 2 Shadow Sizer system at the visualization section.

The optical technique shadow sizer [1] was initially used to identify the flow patterns. This technique consists of a high resolution camera and a source of light, positioned in opposite one to other. The camera captures the shadow of the particles (bubbles, for example) present in the flow, and after processing the images, the diameter, area, perimeter and velocity of the bubbles can be identified. Table 1 summarizes the characteristics of the bench and the main specifications.

Table 1. Main specifications of the bench.

Description	Specification
Total length of the flow visualization field (acrylic piping)	10.3 m
Internal nominal diameters of acrylic pipes (D)	19 mm e 44 mm
Inner diameter of each air distributor valve injector	5 mm

3. EXPERIMENTS

According to figure 3, in the bench, filtered water flows from the reservoir (1) to the piping. Water flow rate is monitored by calibrated electromagnetic flowmeters (2), and the range is established by a valve and a hydraulic pump (controlled by frequency inverter). Compressed air is injected in the line through diametrically opposed four-way distributor valve (3). Calibrated thermal mass flowmeters (4) monitor the air flowrate in each valve.

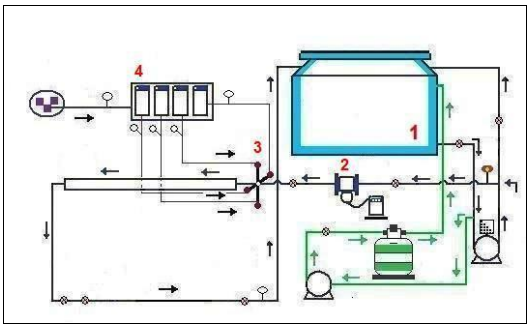


Figure 3 Schematic of the apparatus.

The specifications of calibrated flowmeters used in the bench are described in table 2.

Table 2. Main instruments.

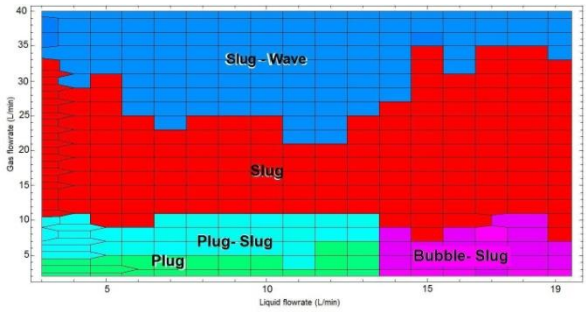
Instruments	Type	Capacity
02 liquid flowrate meters	electromagnetic	20 L/min and 250 L/min
04 air mass flowrate meter	thermal mass	15 L/min
01 digital thermometer	CKT 100	50 °C
Camera of the Shadow Sizer system	Nano Sense MkIII	Exposure time 1000.000 µs and Trigger rate 1000 Hz

Initially, the two - phase flow patterns mapping were elaborated, by relating water to air flow rates (figure 4). As part of the tests, the identification of the region along the tube where there was repetition of a same flow pattern in well defined way was pursued. It was found that this region was positioned 6 m downstream the point of air injection. After that, the mapping was performed by using the shadow sizer optical system. Finally, based on the map of the flow patterns inside the pipe of 25 mm (figure 4 a), it was chosen the ratio of 7 L / min of water and 2 L / min of air as reference condition to investigate the uncertainty in the measurement [4] when using the shadow sizer. Within a set of 1000 images, a pair was selected (360th and 439th images), where the respective images were the beginning of a repeated sequence of the flow behavior. On this selected pair of images, the lengths of the air bubbles were measured by pixel count. For each image, the associated bubble length was a mean of 10 measurements. The conversion of pixel to mm was made by using one line scale as reference standard (see figure 5).

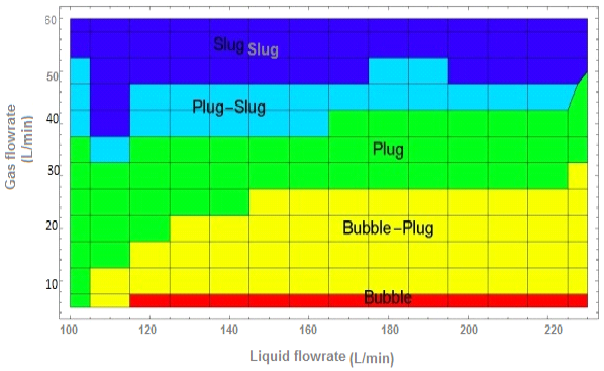
For uncertainty estimation were considered the following input quantities: flow and system repeatability (by measuring equivalent bubble patterns in different stages); accuracy in manual determination of the bubble edges; uncertainty of the reference standard; estimate of pixel length. Table 4 shows the results for both images.

4. RESULTS AND DISCUSSION

Figure 4 shows the maps [3] of characterization of two-phase flow patterns. The patterns were set 6 meters downstream the pipe inlet.



(a)



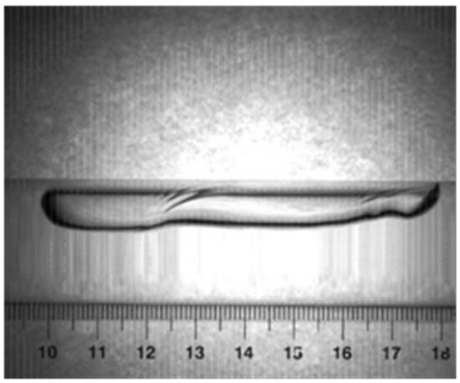
(b)

Figure 4 Maps of two-phase flow patterns for pipes of diameters 25 (a) and 50 mm (b).

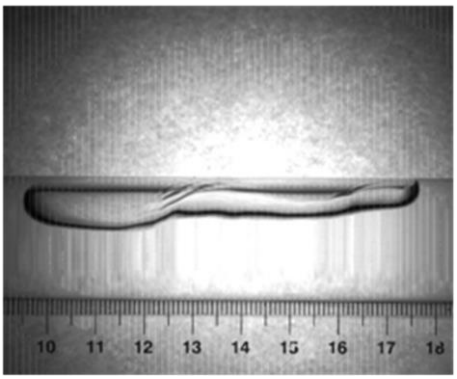
Table 3. Conditions for the two phase flow characterization.

Acrylic tube	Pipe 25 mm	Pipe 50 mm
Ambient Temperature	21 to 26 ºC	23 to 26 ºC
Humidity	57 to 79%	62 to 80 %
Ambient pressure	1015 to 1017 hPa	1007 to 1017 hPa
Liquid Temperature	22 to 26 ºC	25 to 31 ºC
Gas Temperature	20 to 22 ºC	20 to 22ºC
Range of air pressure the pipe inlet	39 to107 kPa	39 to 147 kPa
Time between pulses	10 µs	10 µs
Trigger rate	1000 Hz	1000 Hz

Figure 5 shows the images which were selected for the measurement uncertainty analysis.



(a)



(b)

Figure 5 Two-phase flow pattern named plug. (a) 360th image and (b) 439th image from a sequence of 1000 images

Table 4. Measurement uncertainties results.

	Air bubble Mean Length [mm]	U [mm]	$\nu_{eff,\ 95,5\%}$	k
Image: 360 th	80,91	0,21	407,8	2,01
Image: 439 th	81,21	0,20	178,4	2,01

5. CONCLUSIONS

The mapping for two-phase flow inside horizontal pipes of diameters 25 and 50 mm were performed by using the optical technique shadow sizer. Five flow patterns were developed in each pipe, and more detailed analysis were made on the data set of the pipe of diameter 25 mm. In such pipe, through a set of 1000 collected images, it was observed a repetition of the geometric characteristic of the bubbles in the flow pattern. So, it were selected two images with bubble of similar geometries, and the time interval past between the capture of such images was registered. Although these selected images were taken from different set of sequences of the flow pattern, the difference between the mean bubble length on such images was less than 0,5 mm, and the uncertainties of the length measurement was around 0,2 mm. This is an important finding, since it gives support for discussions about the repeatability of two-phase flow behavior, which is an important condition to be ensured when the performance of multiphase flowmeter must be evaluated. In the continuity of this research, the reproducibility of the behavior of this kind of flow will be included in the analysis.

6. REFERENCES

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