TWO-PHASE FLOW (WATER-AIR) ANALYSIS IN A DISPERSED BUBBLES REGIMES

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Abstract. *The present work investigates experimentally the pressure fluctuations due to discontinuities and internal instabilities in both phases of a two-phase flow. Specifically, is analysed the effects of the dynamic response of a cloud of bubbles in the transient regime. The interactive effects due to the variation of the bubbles volume upon the pressure distribution and on the flow field are very significant. Also, the flow velocity is strongly affected as the concentration of the bubbles increases turning larger the possibility of a global movement of the mixture. The results of this investigation reveal how the presence of the air bubbles affects the nature of the medium throughout the pressure wave, changing the specific gravity of the mixture and the bulk compressibility, therefore, changing the speed of the sound. It is apparent that an increment of the void fraction causes substantial reduction of amplitude response of the bubble.*

Key words*: Group of Bubbles, Two-phase Flow, Discontinuities, Attenuation*

1. INTRODUCTION

Two-phase flow became important since the 40's. The great interest started with the nuclear power plant and its application, but soon afterwards, the aerospace industry, as well as, the chemical and petroleum industries presented their own complex problems. There are, also, many natural situations where the two-phase flow occurs with great importance, such as the case of geothermal sources for energy generation.

Among the great variety of problems, to measure flowrate in a two-phase situation shows an appreciable difficulty in any industrial plant because the random effects of the flow, which are present intentionally or not, change all the hydrodynamic parameters of the flow. Gas bubbles fluctuating in a liquid flow suffer several interactions too much complex for a complete and appropriate mathematical formulation. The existing physical-mathematic models including a complete hydrodynamic interactions of the two-phase flow, as far as the

author's knowledge, are not yet available. In general, all these models totally neglect the internal transient processes, such as the case of the homogeneous or the average time models. Many theoretical models describe the evolution of the two-phase flow structure while neglect important parameters of the two-phase mixture, such as, the amount of gas injected in the flow in terms of quality ($0<x<1$). Only mass, momentum and energy conservation equations are not enough to describe the spatial structure and strong interactions of the two-phase flow. It is necessary to supply a model with supplementary constituent equations, expressing the interfacial laws of transference in terms of dependent variables.

In the two-phase flow, with a dispersed bubbles, complicated interactions appear such as collisions, coalescence among adjacent bubbles, interactions between bubbles and the wall, instantaneous variations of the geometry of the bubbles, affecting the potential hydrodynamic of the flow and causing static pressure and velocity fluctuations as well as increasing the turbulent intensity of the liquid. As a result, variation in the flow field induces changes of the bubbles movement and a more violent buoyancy and heterogeneity inside the flow. Many analytical and experimental studies have been made to discover the mechanism of the two-phase flow, such as the work of Hsieh and Plesset (1961), Wijngaarden (1976,1968,1966), Biesheuvel (1984), Scott (1981), D'Ágostino and Brennen(1989), Nakoryakov et al. (1994), Takahira et al. (1994), Ferreira (1997). All such models, though, cannot represent the actual flow, can only be applied to a restrict flow in very limited conditions. On the other hand, comparisons among results from different researches are also very difficult due to the absence of a similarity parameter, like a non dimensional number, which may embodied the whole phenomenon. So, although a great amount of experimental work, for the flow with bubbles in different systems liquid-gas, little basic information are supplied to give the actual view of the physical phenomenon. Thus, the basic knowledge of the mechanism of this complex flow is still very limited, although bubbles of gas in liquid are a very familiar and have been studied since long time.

The present work investigates experimentally the fluctuations of local pressure of the two-phase flow in a dispersed bubble regime seeking new clues to solve this puzzle flow. The purpose of this study is to get an overall information looking the flow as a whole. A mixture of water and air flows through a horizontal pipe of 50 mm internal diameter at low total pressures of 250 kPa. The study gives emphases to the following topics:

1) pressure fluctuations frequencies and
2) pressure fluctuations intensity produced by the dynamic of the bubbles;

2. EQUIPMENT AND PROCEDURE

The experimental data were obtained from the test circuit shown in Figure 1. The test circuit is part of the calibration gravimetric rig of the Turbomachine and Flow Measurement Laboratory - LTMF used to calibrate liquid flowmeters from 0.1kg/s up to 5.0 kg/s with an extended ($k_{95\%} = 2$) uncertainty of $\pm$ 1.0 % full scale (FS). The rig comprises by three different sections: the inlet section; the developing section and the test section. The inlet section has a enlarged cross section tube of 150mm diameter with a flow straightener to condition the flow and prevent large eddies, swirls as well as possible secondary flows and fluctuations produced by the pump or coming from previous bends and several hydraulic components. A vent installed on the top of the inlet section eliminate air from other sources different from the measured one. The developing section consists of a long straight pipe of 50 diameter mm with an equivalent length of 60 diameter (3000 mm) before the test section. The objective is promote a fully development of the flow profile.
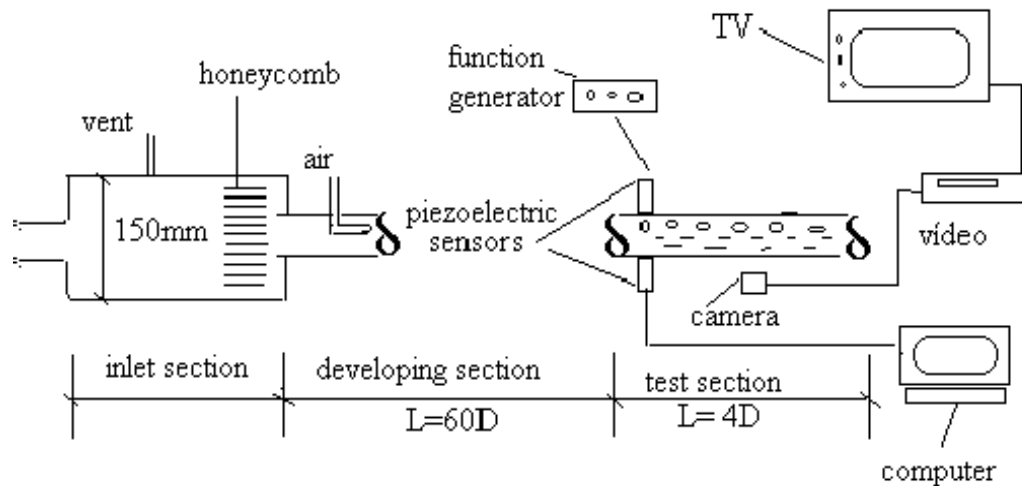
Figure 1 Test Section

The test section consists of a horizontal acrylic tube of 50 mm of diameter internal, with two piezoelectric sensors vertically opposite installed. The transmitter sensor is the one on the top and the receiver the one on bottom of the tube. The piezoelectric sensors have a resonance frequency of 140 kHz and response signal from 4 to 20 mA.

The measured air is injected by a small tube in a "L" shape through many small holes of 10mm diameter. This solution allows the air being mixed in water with vertical movement.

A function generator drives a 140 kHz sinusoidal wave signal to the transmitter sensor on the top of the pipe. The ultrasonics signals reach the piezoelectric receiver sensor, diametrically installed, suffering variations due to the presence of bubbles altering the intensity and phase related to the incoming signal. The amount of bubbles varies randomly with the time and with the flow established. The signals from the piezoelectric receiver were amplified and demodulated to remove noise and the high frequency carrier signal. The treated signal reveals the random characteristic of the flow.

In order to acquire the experimental results a fast acquisition system, was used. The data system may run from a frequency of 100 up to 300 kHz acquiring up to 100.000 points for each test. At the same time, in a synchronised images of the flow is recorded onto a DV video tape by a digital VCR through a CCD digital monochrome video camera. This video camera allows shutting at a variable speed ranging from 1/30 to 1/10000 seconds in a discrete way of eight options. All the images were digitalized and stored into a microcomputer by means of a interface board.

3. EXPERIMENTAL RESULTS AND ANALYSIS

The measurements were made for different flow rate of the mixture water and air. This section presents some obtained results. The Figure 2 shows the pressure fluctuations in the domain of the time for the flow single - phase with flow rate of water of $(1,03\pm0,01)$ kg/s and for two-phase flow with a flow rate of $(1,03 \pm0,01)$ kg/ s of water and$(1,0775\pm 0,001)\times10^{-5}$ kg / s of air, so much in the domain of the time and the spectrum of corresponding frequency.
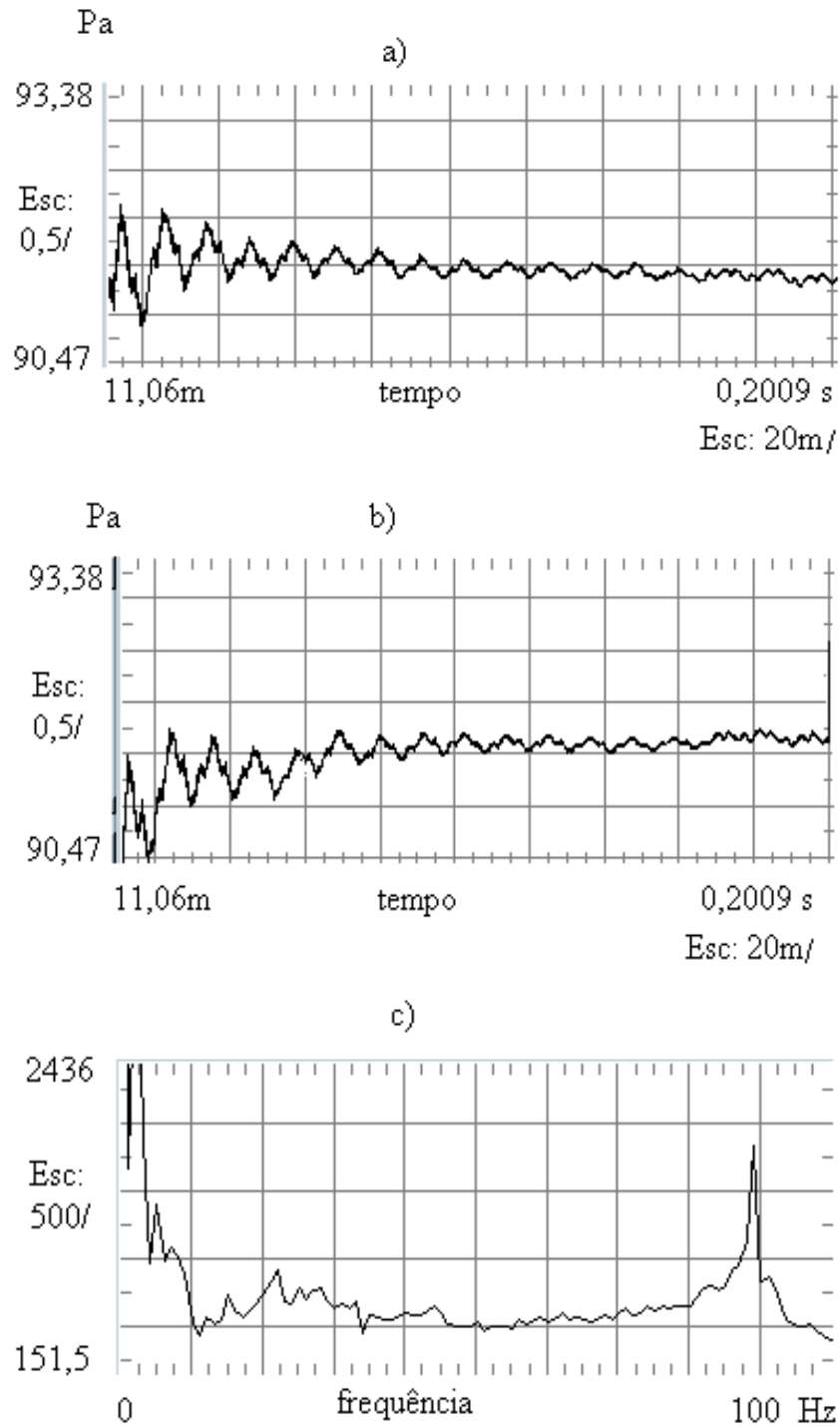
Figure 2   Pressure Fluctuations : a) Monophase Flow m = (1,03 ±0,01) kg/s (water)
b) Two-phase Flow m = (1,03 ±0,01) kg/s (water) and m = (1,0775± 0,001)x10^{-5}
kg/s (air) c) Frequency Spectrum of Two-Phase Flow

The Figure 3 exhibition the pressure fluctuations in the domain of the time for the flow single phase with flow rate of water of (1,37 ±0,01) kg/s and for the two-phase flow with flow rate of (1,37±0,01) kg / s of water and (2,155±0,001)x10^{-5} kg / s of air in the domain of the time and the spectrum of corresponding frequency.
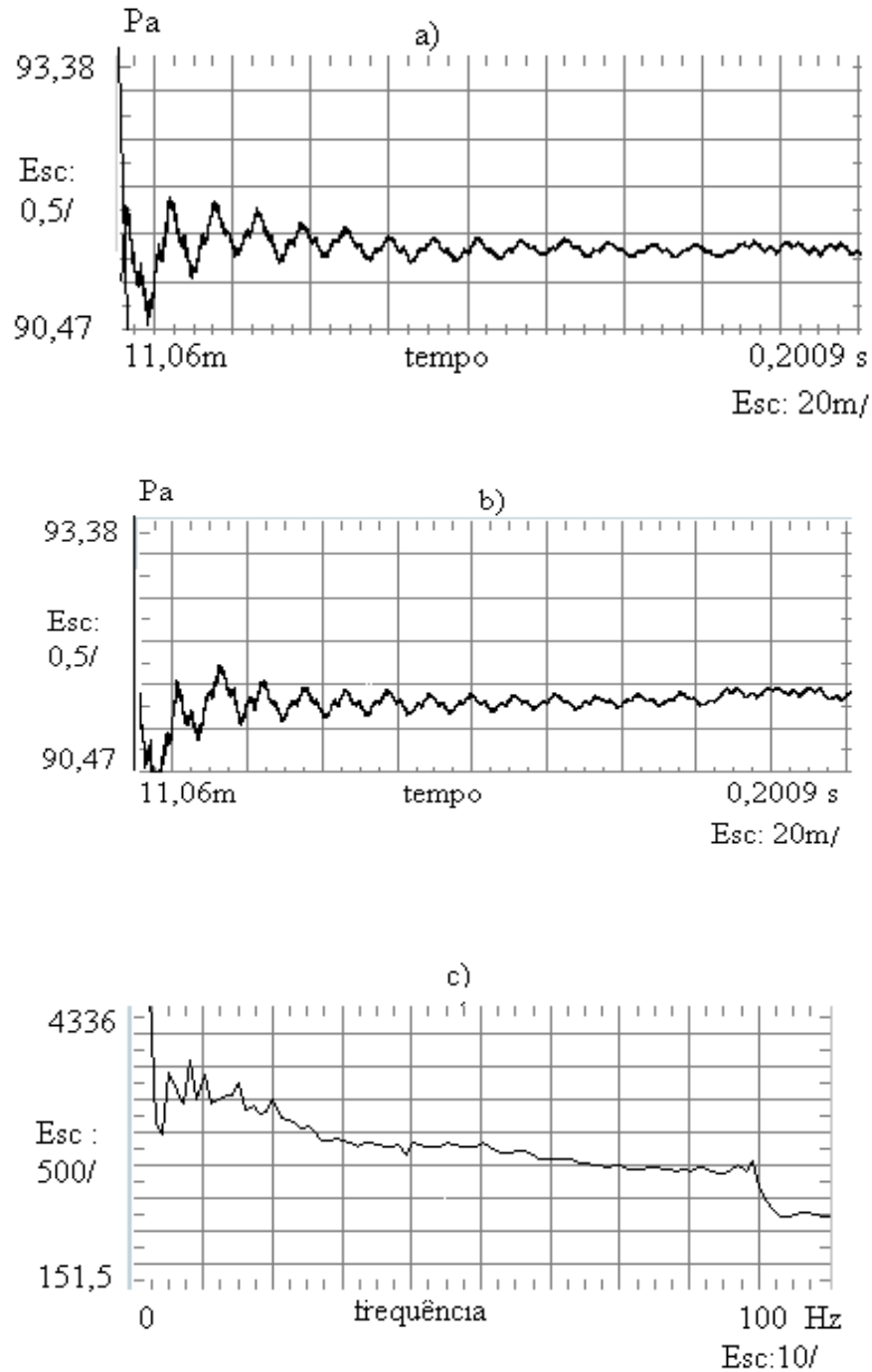
Figure 3 Pressure Fluctuations : a) Monophase Flow m = (1,37 ±0,01) kg/s (water)
b) Two-phase Flow m = (1,37 ±0,01) kg/s (water) and m = (2,155± 0,001)x10^{-5}
kg/s (air) c) Frequency Spectrum of Two-Phase Flow

Different correlation among flow single phase and two-phase they were applied. They were made several analysis, so much in the domain of the time, as in the one of the frequency, for different tested fractions of emptiness. Although the Figures 2 and 3 are private cases, they are representative and very similar to the other made tests. Of the graphs of the Figures 2 and 3, it was observed that with the introduction of the dispersed phase (air bubbles) in the flow with water:

· the intensity of the fluctuations in the two-phase flow is larger an order of greatness or more than the one of the flow single phase for the same water flow rate;

· the spectrum of frequency of the two-phase flow there are some well defined picks of frequencies in both flows, which probably represent some supported of flow measurements effects of the own;

· In contrast with the flow single phase, the spectrum of fluctuations of each hydrodynamic parameter is characterised by a maximum fall in low frequency of the order of 1-10 Hz.

Analysis of several pressure diagrams in the two-phase flow situations reveals the presence of a so called progressive waves which alters the time and space structure of the flow.

By using of analytic expressions proposed by Fokin, (1995), for the transient two-phase flow, the intensity of the fluctuations of pressures was calculated in form of root mean square values. The correspondent values used was for test established in Figure 2 and 3 and the mean value achieved was 0,81213 Pa. Comparison between experimental and analytical results showed agreement. The actual pressure fluctuations represent a superimposition a harmonic process with an random noise.

The Figure 4 shows the pressure fluctuations produced by the addition of the dispersed phase (bubbles) in the flows corresponding to the Figures 2.
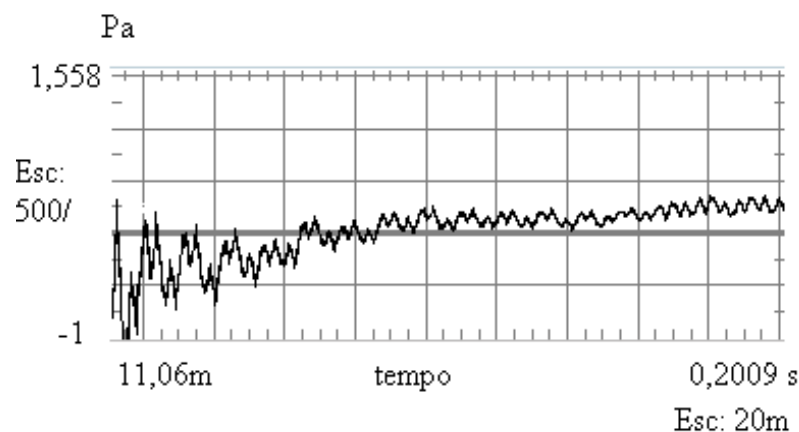

Figure 4 Pressure Fluctuations produced by Dispersed Phase (Bubbles): Signal of the Difference Two-Phase Flow and Monophase of Figure 2.

The results show non linear effects caused by radial fluctuations of the bubbles in the liquid. Oscillations produced by group of bubbles affect the basic flow turning impossible an analytic treatment of the flow single phase.

According to Scott, (1981), oscillations produced by bubbles are describe by certain eigenvalue problems, which give the normal manners and corresponding frequencies of oscillations. These manners represent collective oscillations of the system of bubbles, and it cannot in general, to be attributed to private bubbles.

4. CONCLUSIONS

Although to present analysis it doesn't allow an accuracy of the quantitative results, not having given enough to be conclusive, the results of this investigation reveal a number of

important effects in flows confined with bubbles. A pressure fluctuation signal in a bubbly flow is complex, due the fact the continuos phase conducts pressure fluctuations very well.

Attenuation extremely high are produced in water contends suspended bubbles of air. The presence of the air bubbles affects the nature of the middle through the ones which the wave this progressing.

The power spectrum, also, showed some selected frequencies that may be referred to installation effects and some to the flow behaviour.

It was observed that an increment of the void fraction causes a substantial reduction in the bandwidth response of the dynamic of the bubble.

The work is still underway and in the near future some of theses questions will certainly be answered.

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