4ème Conférence Internationale des Energies Renouvelables (CIER-2016)
Proceedings of Engineering and Technology – PET
Vol.16, pp.27 - 31

Measurement of the Frequency of Passage of Intermittent Structures in Two-Phase Flows

A.ARABI[*1], Y. SALHI[*2], Y. ZENATI[*3], E.K. SI-AHMED[*#4] et J. LEGRAND[#5]

[*] *Laboratoire de Mécanique des Fluides Théoriques et Appliquées, Faculté de physique, U.S.T.H.B, Alger, Algérie.*

[1]abderraoufarabi@gmail.com

[2] ysalhi@usthb.dz

[3]youcef83@gmail.com

[4] ek_siahmed@yahoo.fr

[#] *GEPEA, Université de Nantes, CNRS, UMR 6144, CRTT-BP406, 44602 Saint –Nazaire, France.*

[5]Jack.Legrand@univ-nantes.fr

Abstract- In this study, we used the Power Spectral Density (PSD) to study the frequency of the passage of the liquid slug for the slug and pseudo-slug flows of a water-air two-phase flow in a horizontal pipe with an internal diameter of 40 mm. The results obtained were compared with those obtained by the counting method. It has been found that in the case of the slug regime, the PSD is characterized by the presence of a single peak, whereas in the pseudo-slug flow, it may be unimodal or bimodal. It has also been found that the results obtained by the PSD are far from the results obtained by the counting method for the two regimes studied and therefore the PSD can only be used to qualitatively quantify the frequency of the passage of the intermittent structures of the slug and pseudo-slug flows.

Keywords—Two-Phase flow, slug, pseudo-slug, frequency, PSD, counting

I. INTRODUCTION

Two phase flow phenomena occur in a wide range of industrial installations. Among the possible flow configurations, slug flow regime is encountered for a wide range of gas and liquid superficial velocities. This flow regime is characterized by an intermittent behavior: in fact, the flow is composed of a pocket of gas flowing on a liquid film followed by a liquid slug which completely filling the cross-section of the pipe (Fig. 1). This intermittence of the flow results in large pressure fluctuations which causing vibrations and erosion of the pipelines. Moreover, the passage of the liquid slugs can lead to the phenomenon of resonance causing the destruction of the pipes.

The intermittence of the slug regime is quantified quantitatively by the study of the frequency of liquid slugs passing through the pipe in a given time interval. Despite five decades of study, there is still much to understand about the frequency of liquid slugs and this is essentially due to the lack of a complete theoretical description of the phenomenon. Various empirical or theoretical correlations have been developed (Gregory and Scott [1], Taitel and Dukler [2], Heywood and Richardson [3], Nydal and al. [5], Fossa et al [6], Shea et al [7]).

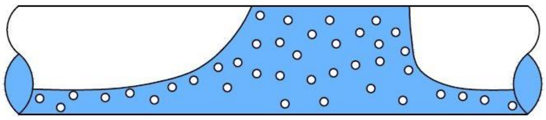


Fig. 1 Schematic representation of a slug flow

Care must be taken to differentiate between slug regime and pseudo-slug regime, which is also characterized by intermittence of the two phases, but with the difference that this regime is characterized by highly aerated slugs front which block the pipe cross section momentarily and by roll waves that not reach the top of the pipe (Fig. 2). Hubbard [8] has shown that in the slug regime, the liquid slugs move at a speed approximately equal to that of the gas velocity, the pseudo-slugs and the large waves move at a speed lower than the gas velocity. Lin and Hanratty [9] proposed the cross-correlation function between two pressure signals to distinguish between the two regimes.

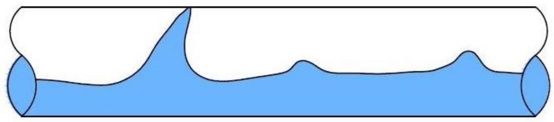


Fig. 2 Schematic representation of a pseudo-slug flow

This work aims at the use of the Power Spectral Density (PSD) to quantify the frequency of the passage of the slugs from pressure drop time series in slug and pseudo-slug flow regimes. The obtained results were compared with those obtained by the counting method.

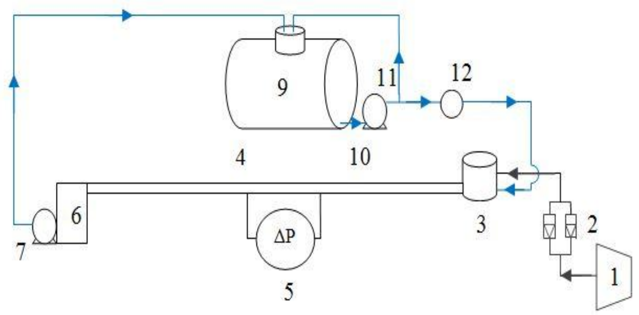
II. EXPERIMENTAL APPARATUS

The study was carried out by using two-phase water-air loop with an internal diameter of 40 mm and a length of 13 m horizontal pipe and which the diagram is given in Fig. 3. The loop is designed to generate a co-current water-air two-phase flow. The air, which circulates in an open circuit, comes from the compressor and measured via two rotameters mounted in

ISSN 2356-5608

parallel. The liquid component is circulated in closed circuit and introduced in test section via centrifugal pump. The water flow is fixed through a control valve and measured using an ultrasonic flowmeter GE PT 878 type. The study was performed using plexiglass pipe to facilitate the visualization of the flow regimes. The air-water mixture flow through the tube into a separator, where air is escaped and water is reused.

The pressure drop signals were acquired using a differential pressure sensor Freescale MPX-2010 DP. The sensor terminals were connected to two pressure tap at 6.49m and 7.17m downstream the inlet mixer. The data were acquired with a frequency of acquisition equal to 200 Hz for a period of 40s.



1: compressor; 2: gas flowmeters; 3: liquid-gas mixer; 4: plexiglass pipe, differential pressure sensor, 6: settling vessel; 7: pump; 9: liquid reservoir; 10: pump; 11: by-pass; 12: ultrasonic flowmeter.

Fig. 3 Description of experimental setup

III. SLUG FREQUENCY DETERMINATION METHODS

Two methods are commonly used to obtain slug frequency. The first consist in counting the number of slugs per unit time in pressure time series. The other approach is based on the signal analysis of wall pressure fluctuations or void fraction signals in frequency domain.

A. *Power Spectral Density (PSD)*

In order to study physical phenomena, we resort to time series which are obtained experimentally by the measurement at regular intervals of the physical quantity studied. The Power Spectral Density (PSD) describes the distribution of the energy of a temporal signal across the frequency domain; it is used to study the periodic phenomena and consists of the extraction of the frequencies present in the time series.

Since the frequency of the slugs can be assimilated to the periodicity of the slug regime, it is obvious to use the PSD to determine the frequency of the slugs from a time series of the pressure drop of two-phase slug flow.

B. *Counting method*

The counting method is the simplest method used to calculate the frequency of the slugs from a differential pressure signal, in fact every time a slug passes between the terminals of the pressure taps it is accompanied of the formation of a peak in the signal of the pressure drop. By counting the number of peaks (N) and the acquisition time (T), the frequency of the plugs (Fc) is calculated with the following formula:

$$Fc=N/T$$

IV. RESULTS AND DISCUSSION

First, a distinction was made between the slug flow and the pseudo-slug flow. The distinction is based on visual observation of the flow regimes as well as the visualization of the differential pressure signals as suggested by Weisman et al. [10]. In fact, the slug flow, as shown in Fig. 4, is characterized by the presence of peaks, indicative of the passage of the slugs, spaced by a regular space with a length greater than the width of the peak representing the passage of the gas pocket above the liquid film. Fig. 5, representing the signal of the pressure drop of a pseudo-plug flow, is composed of peaks, indicative of the passage of the slugs which block the pipe for a reduced period of time as well as small peaks, representing the passage of roll waves whom not reach the top of the pipe. It will also be noted that in the pressure signal of a pseudo-slug flow, the time between two peaks is very small compared to the slug flow.

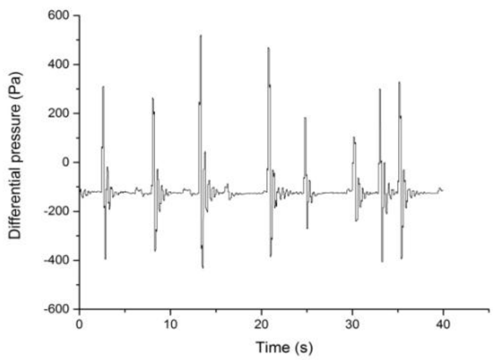


Fig. 4 Signal of pressure drop of a slug flow (Jl= 0.235 m/s and Jg= 1.857 m/s)

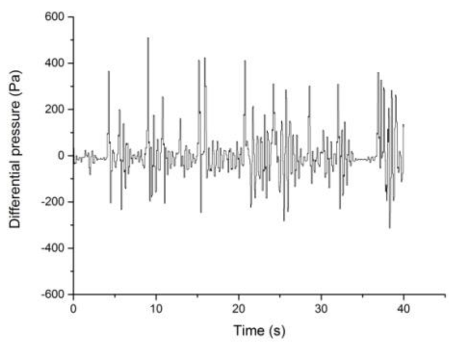


Fig. 5 Signal Signal of pressure drop of a pseudo-slug flow (Jl= 0.371 m/s et Jg= 2.122 m/s)

ISSN 2356-5608

Fig. 6 shows an example of PSD in the case of the slug flow, it is clear that it is a unimodal spectrum composed of a single dominant frequency representing the frequency of the passage of the liquid slugs. The spectrum of the frequencies of the pseudo-slug maybe unimodal with one dominant frequency or bimodal (Fig.7) when two dominant frequencies are present, showing the existence of at least two important structures each with its own frequency.

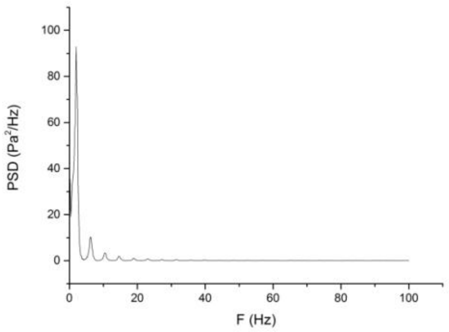


Fig. 6 Example of a unimodal frequency spectrum (Jl= 0.235 m/s et Jg= 1.857 m/s)

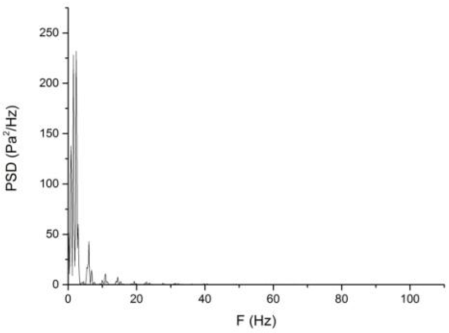
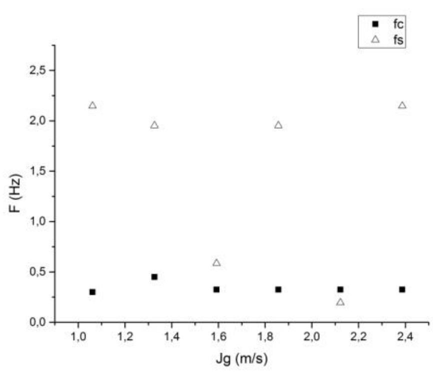
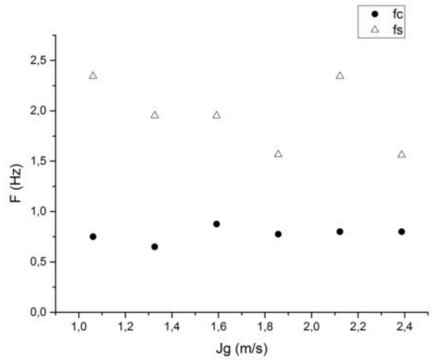


Fig. 7 Example of a bimodal frequency spectrum (Jl= 0.371 m/s et Jg= 2.122 m/s)

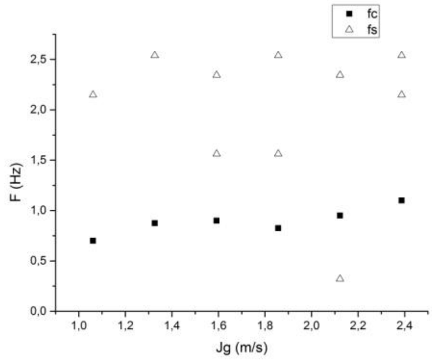
a) Jl = 0.235 m/s



b) Jl = 0.291 m/s



c) Jl = 0.319 m/s



d) Jl = 0.373 m/s

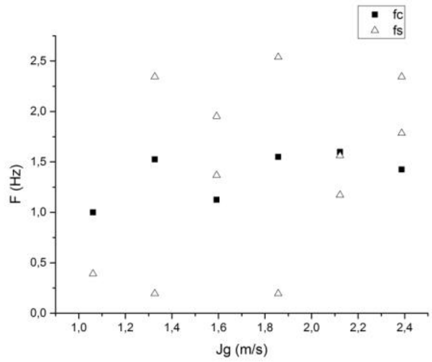


Fig.8 Comparison of the PSD and counting method for the calculation of frequencies of intermittent structures for different superficial liquid velocity

The dominant frequencies obtained from the PSD (fs) were compared with those found by the counting method (fc), the results were plotted as a function of the gas surface velocities for different liquid surface velocities (Fig. 8). It is clear that the PSD method tends to overestimate the frequency of flow compared to the counting method. This difference can be explained by the fact that the frequency of the passage of the liquid slugs is not a standard periodic function and therefore the time of passage between two successive slugs and the amplitude of the peaks are not constant as reported by Woods and Hanratty [11]. The disagreement between the results of the two methods is also due, in the case of the pseudo-slug flow, to the subjectivity of the counting method; In fact, it is

ISSN 2356-5608

rather difficult to distinguish between the peaks representing the passage of the slugs with the peaks caused by the passage of large waves which do not touch the wall. It is also observed that the data of results given by the two methods have the same trend, which makes us say that the PSD can be used to measure qualitatively the frequency of the passage of the intermittent structures of an air-water two phase flow. It can be seen that in the cases J1 = 0.319 m / s and J1 = 0.373 m / s, which respectively from Jg = 1.592 m / s and jg = 1.326 m / s, we note the existence of a second frequency in the spectrum (bimodal spectrum) which results in the occurrence of a bifurcation in the plotted frequency from the PSD in Fig. 6c and 6d.

V. CONCLUSION

In this work, we studied the frequency of the intermittent structures of slug and pseudo-slug flow regimes in horizontal water-air two phase flow. Frequency measurements were made by using two commonly used methods: the power spectral density and the counting method. It has been found that in the case of a slug flow, the frequency spectrum is characterized by a single dominant frequency and that, in the case of the pseudo-plug regime, it contains one or two dominant frequencies. The frequency values obtained by the PSD were found to be quite far from the values found by the counting method which makes us say that PSD cannot be used to quantitatively predict the frequency of passage of intermittent structures of slug and pseudo-slug flow.

REFERENCES

[1] G.A. Gregory and D.A. Scott, “Correlation of liquid slug velocity and frequency in horizontal concurrent gas–liquid slug flow”. *AIChE J.*, Vol. 42, pp. 901–907, 1969.

[2] Y. Taitel and A.E. Dukler, “A model for slug frequency during gas-liquid flow in horizontal and near-horizontal gas-liquid flow”, *Int. J. of Multiphase Flow*, Vol. 19 (5), pp. 829-838, 1977.

[3] N.I. Heywood andJ.F. Richardson, “Slug flow of air—water mixtures in a horizontal pipe: Determination of liquid holdup by γ-ray absorption”. *Chemical Engineering Science*, Vol.34 (1), pp17-30. 1979.

[4] O.J. Nydal, S. Pintus et P.Andreussi, “Statistical characterization of slug flow in horizontal pipes”, *Int. J. Multiphase Flow*, Vol. 18, pp. 439–453. 1992.

[5] Manolis, I., Mendes-Tatsis, M., Hewitt, G., “The effect of pressure on slug frequency on two-phase horizontal flow”. *Presented at the 2nd International Conference on Multiphase Flow*, Kyoto, Japan. 1995.

[6] M. Fossa, G. Guglielmini and A. Marchitto, “Intermittent flow parameters from void fraction analysis”, *Flow Meas. Instrum.,* Vol. 14, pp. 161-168. 2003.

[7] R. Shea, H. Eidsmoen, M. Nordsveen, J.Rasmussen, Z. Xu and J. Nossen, “Slug frequency prediction method comparison”. *BHRG Multiphase Production Technology Proceedings*, Banff, Canada. 2004.

[8] M.G. Hubbard, “An analysis of horizontal gas-liquid slug flow”. Ph.D. Thesis, Univ. of Houston, Texas, USA, 1965.

[9] P.Y. Lin and T.J Hanratty, “Detection of slug flow from pressure measurements”. *Int. J. Multiphase Flow*, Vol. 13(1), pp. 13-21, 1987.

[10] J. Weisman, D. Duncan, J. Gibson and T. Crawford, “Effects of fluid properties and pipe diameter on two-phase flow patterns in horizontal lines”, *Int. J. Multiphase Flow*, Vol. 5(6), pp. 437-462, 1979.

[11] B.D. Woods and T.J. Hanratty, “ Influence of Froude number on physical processes determining frequency of slugging in horizontal gas–liquid flows”, *Int. J. Multiphase Flow*, Vol. 25, pp. 1195–1223.1999.

ISSN 2356-5608