ENCIT-2018-0809
LOSS OF PIPELINE PRESSURE WITH SINGLE-PHASE AND BIPHASIC

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Abstract. This work aims at the study of loss of charge in single phase and biphasic flows, from a sample of data obtained with empirical tests in an experimental apparatus. Liquid and air flow values were selected for the tests, obtaining main results of Reynolds number, void fraction and reduction of trawl in the pipeline. The results obtained could be explained with a friction analysis of the flow with the walls of the pipe. The roughness of the pipe was a determining factor for the loss of load in the single phase flow. The presence of the gas phase was determinant for the reduction of the loss of load along the pipe, due to the reduction of the friction of the flow with the walls.

Keywords: Load loss, Roughness, Drag....

1. INTRODUCTION

Multiphase flows are found in numerous natural and industrial processes. In nature, according to Dalla Maria *et al.* (2016), sandstones, fog, transport of sediments in rivers, volcanic lava, as well as the blood flow inside veins and arteries stand out. Also according to Dalla Maria *et al.* (2016), in the industrial sphere, the processes of combustion and gasification, transport of particulates and emulsions, fluidized beds, distillation towers, cooling towers, condensers, cooling system of nuclear reactors and production of oil and gas in oil fields.

The study of a turbulent flow is of great importance, because there are many practical applications for this study. According to Brunetti (2008), this type of flow is characterized by the macroscopic random motion of fluid particles, that is, the velocity presents components transverse to the general movement of the fluid set, which prevents the use of valid simple equations. In this sense, the evaluation of the turbulent flow is done by means of experimental data collected and manipulated of which the principal parameter to evaluate the type of flow, the Reynolds number, is studied. For values of Reynolds numbers greater than 2400, the flow is classified as turbulent.

A consequence of this turbulent behavior of the fluid is the difficulty of studying the loss of charge, which in the analysis of internal flows in pipes or ducts, it is common that it is necessary to determine it. According to Vilanova (2016), the pressure loss is the effect that the pipe imposes on the fluid system, arising from the effects of fluid viscosity and can be determined by taking into account the localized effects imposed by components such as curves, tees, knees , valves or other components that are mounted in the fluid flow, and by the normal viscous effects imposed by linear piping that depend on factors such as flow velocity, pipe geometry (length and diameter), pipe surface roughness and viscosity and specific mass of the fluid.

Currently, there are several studies focused on the study of turbulence with the objective of developing effective methods to reduce friction and the justification for these studies is quite convincing. Willemsens (2013) says that the optimization of energy resources mainly for economic reasons, for example, is one of the goals of the technological area. One of the ways to save is to reduce friction. In this way, the present work will study the development of the monophasic and biphasic flow and the consequences in the reduction of the drag.

2. METHODOLOGY

For this work, the data sampling was collected in an experimental apparatus formed by a horizontal pipe with a constant diameter of 1 inch and a total length of 6 m. The liquid heights H_1, H_2 and H_3 were taken as pressure measurements along the length of the pipe. The schematic of the apparatus is shown in Fig. 1 below.
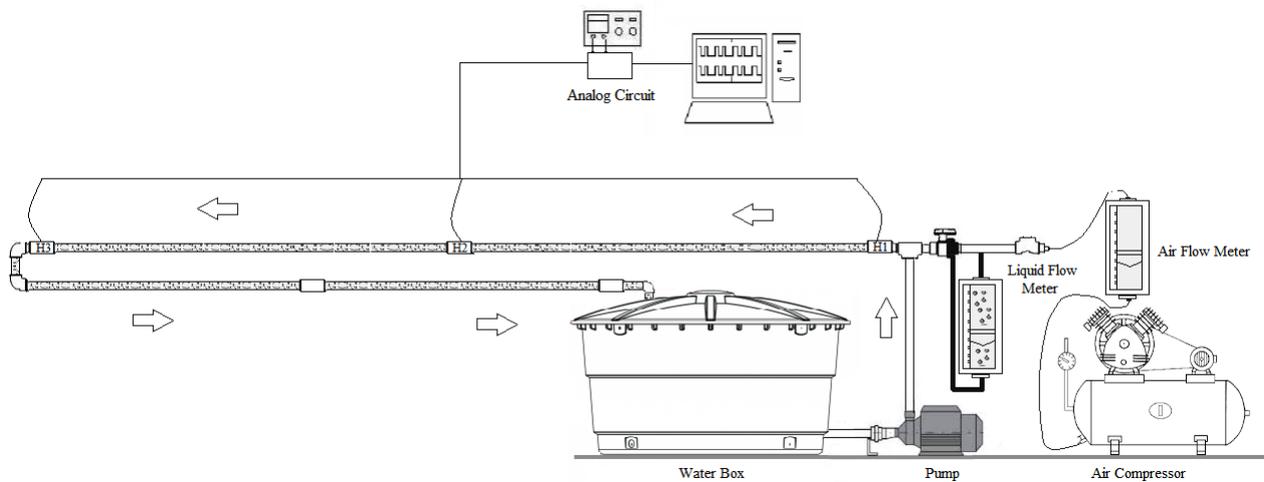

Figure 1. Schematic of the experimental apparatus.

The flow was formed by pumping the fluid stored in the water box into the pipeline. As initial operating parameters, the liquid flow values set out in the table below were chosen for flow tests in single phase and later two phase. Initially, the airflow was assumed to be zero to investigate the performance of the empirical test circuit in the single-phase system. Thus, the pressure drop along the pipe was measured for different Reynolds numbers, defined from the liquid flow only.

For the biphasic flow, the air was injected into the piping so that the effect of the void fraction could be studied in the trawl of the fluid with the walls of the pipe. In this sense, the air flow rates to be combined with the liquid flow rates were defined, where for each liquid flow rate of 40 and 50 L / min three air flow values would be combined. In the Tab. 1 below are the values chosen for the tests in the biphasic system.

Table 1. Parameters for biphasic flow.

Type of system	Liquid Flow	
Single phase	40	50
Biphasic	40	50
	Air Flow	
	15	
	20	
	25	
	30	

After choosing the operational parameters, the data was collected so that the loss of load could be analyzed along the pipeline considering possible errors and the degree of confidence of the data.

2.1 Void Fraction

Ofuchi (2011) defines the void fraction as the ratio between the cross-flow areas that are occupied by gas and liquid. In order to study the biphasic flow, air flows of 15, 20, 25 and 30 L/min were assumed for each liquid flow rate of 40 and

50 L/min. Nouri *et al.* (2012) , in their work, calculated the average vacuum fractions from Eq. (1).

$$\alpha = \frac{Q_{air}}{Q_{liquid} + Q_{air}} \tag{1}$$

3. RESULTS AND DISCUSSIONS

Nouri *et al.* (2012), in their methodology, initially adopted the air parcel being null and thus it was possible to determine the Reynolds numbers of the liquid flows in the single-phase flow. The Reynolds number represents the main characteristic of the study flow. Brunetti (2008) states that the pressure drop can not be evaluated from analytical equations. For this, then, one must resort to experimental data for a dimensionless analysis and to correlate them. Therefore, the results of mean velocity and Reynolds number for single-phase flow were obtained at flow rates of 40 and 50 L/min.

Table 2. Mean velocity and Reynolds number for flow rates of 40 and 50 L/min

Liquid Flow (L/min)	Mean Velocity (m/s)	Reynolds number
40	1,316	3745,69
50	1,645	4682,11

In the literature of Brunetti (2008), the Reynolds number greater than 2400 implies that the flow is of the turbulent type, behavior that was observed for the tests with the two initially proposed flows. To obtain the results of the above table, the diameter ($D = 0,0254m$), the flow velocity v, the specific mass ($\rho = 997,05kg/m^3$) and the dynamic viscosity of the fluid ($\mu = 0,0089N.s/m^2$) were used.

During the study, at the same time that the Reynolds numbers were evaluated, the analyzes of the heights H_1, H_2 and H_3 obtained in the tests were made. It can be seen that the mean values of height, within a sampling of just over 2000 thousand points, showed a 95% acceptable level of confidence, varying from 0.01 to 0.02 in the tests of the single-phase system and 0,03 to 0,05 in the biphasic system, giving credibility to the results.

It is also noted that there is the loss of load along the pipe and, from Vilanova (2016), this can be explained by the friction imposed by the roughness of the pipe walls, making movement contrary to the flow and thus causing the fall of pressure.

In Nouri *et al.* (2012), for the two-phase flow, considered the flow of air along with the liquid. For each liquid flow chosen, the flow of air passing through the pipe was changed. Thus, it was possible to obtain the void fraction in the pipe for each combination of air and liquid flow and to associate it with the calculated Reynolds numbers of the air. In Figures 2 and 3 below, it is possible to note the relationship between the vacuum fraction and the pressure drop, and it can be seen that the larger the void fraction, the lower the pressure drop along the pipe, for both Reynolds at 3745,69 and 4682,11.
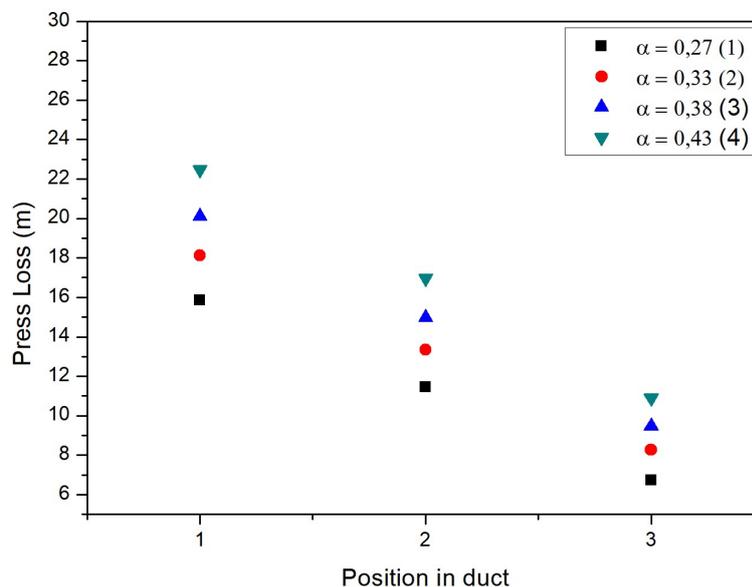

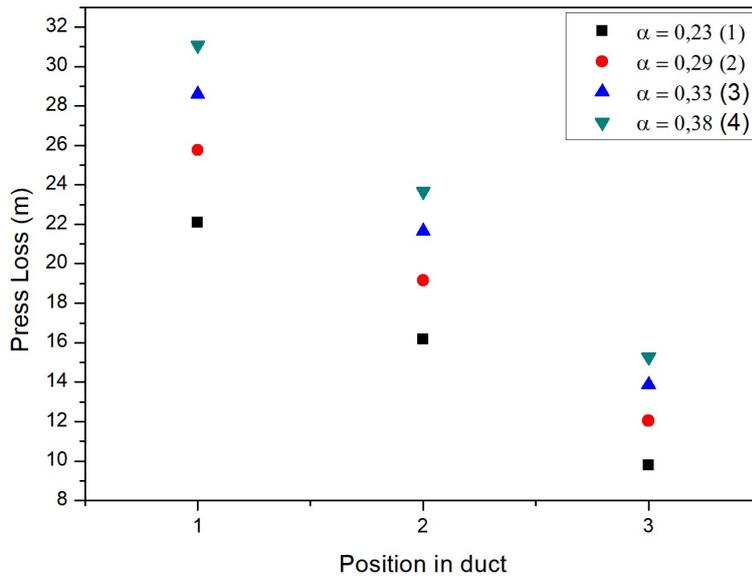Figure 2. Loss of pressure along the pipe to Reynolds equal to 3745,69.

Figure 3. Pressure loss along the pipe to Reynolds equals 4682,11.

Based on the results, the maximum reduction of the pressure drop found in this work was 52.63% and was observed for the maximum value of void fraction of 0,43, when the number of Reynolds of the air injected was 125382,42 . This behavior can be observed among the other results, where there is an increase in the void fraction at the same time that the pressure drop reduction value increases for all Reynolds number values. Table 3 below shows the values obtained for reducing the pressure drop.

Table 3. Reduction of pressure drop for Reynolds numbers of air.

Reynolds Number		Void Fraction	Drag Redution (%)
Liquid	Air		
3745,69	62691,21	0,27	40,04
	83588,11	0,33	44,45
	104485,35	0,38	48,49
	125382,21	0,43	52,63
4682,11	62691,21	0,23	30,93
	83588,11	0,29	38,10
	104485,35	0,33	42,31
	125382,21	0,38	46,27

With these results, the behavior of the data can be observed in Fig. 4, where the reduction of the pressure drop can be observed according to the void fractions obtained.
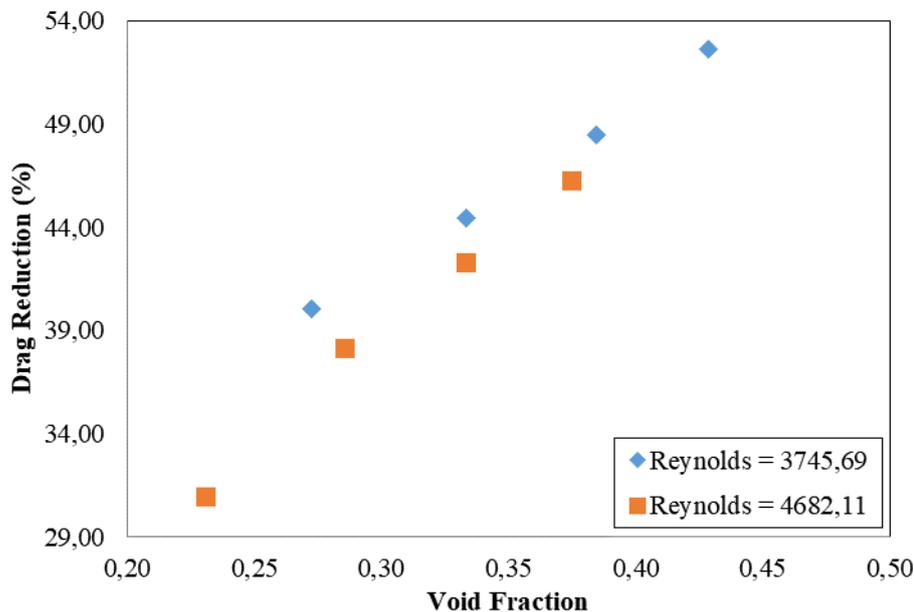
Figure 4. Reduction of pressure drop as a function of void fraction

According to Nouri *et al.* (2012), the increase in void fraction increases the effect of bubbles on friction stress and decreases pressure drop in the tube. In addition, at the lower Reynolds numbers, the effect of void fraction on drag reduction is greater than its effect on higher Reynolds numbers. In the present study, this result can be observed.

4. CONCLUSION

Many flow studies require experimental data analysis due to several factors. One of them is the type of flow, where the behavior of the fluid may present instability and analytical models do not meet the needs of these studies. In the present work, the turbulent flow was observed in an experimental apparatus, in which the loss of load was observed due to the friction of the smooth pipe. In the fluid literature, this result can be observed.

In this sense, in order to reduce the observed loss of load, it was evaluated how the vacuum fraction method makes possible the search for this result, from the characterization of a biphasic flow, where the values found attest that, therefore, the air injection in the tube flow can be used to decrease flow transfer losses.

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