METHOD FOR MEASUREMENT OF TWO-PHASE FLOW RATE BASED ON PIPE VIBRATION

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Abstract: This work aims to develop a method for the measurement of the two-phase flow rates of liquid and gas. An experimental investigation has been carried out to obtain correlations between the pipe vibration an two-phase flow mixture superficial velocity and relationships between pipe frequency response functions and the volumetric fractions.

Key words: flow rate measurement, two-phase flow, pipe vibration.

1. INTRODUCTION

The two-phase flow of gas and liquids is usually encountered in piping systems and process plant equipment in the oil and gas, nuclear energy and chemical processing industries. The measurement of the two-phase flow rates is particularly important in the oil and gas production. Considerable research has been conducted into the development of accurate two-phase and multiphase flow meters.

This work presents the preliminary results of an experimental investigation on the measurement of two-phase flow rates of liquid and gas mixtures based on the analysis of pipe vibration. The two-phase flow vibration excitation mechanism is known to be related to the flow momentum variation due to the presence of phases with distinct densities. The two-phase flow dynamic forces acting in some pipe elements like bends and elbows can produce high levels of vibration. The excitation mechanism of piping vibration due to the two-phase flow is a combination of narrow-band random and periodic forces components. The vibratory response due to the two-phase flow excitation also depends on pipe geometry, pipe material and boundary conditions.

2. PURPOSE

This work aims to verify the possibility of using the pipe vibration response of the two-phase flow conveying pipe to measure the flow rates of liquid and gas, providing a low cost, non intrusive method that could be easily implemented also in existing piping systems. In addition, the proposed method would offer the possibility of a nearly real time measurement of the two-phase flow rate.

3. METHODS

In the present work, the authors investigated the correlation between piping vibration and the two-phase flow rates of air and water. To obtain higher vibration levels, the air-water loop shown in Fig. 1 with pipe test sections composed of straight pipes and bends were employed.

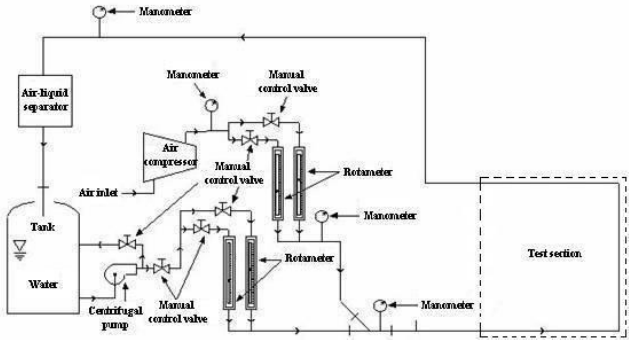

Fig.1. Schematic diagram of the air-water loop.

The two-phase flow dynamic forces acting on the bends increase the pipe vibration and consequently improve the sensitivity of the method to variations in the flow rates. Pipe vibration response was measured with accelerometers mounted to the pipe. In order to determine the flow rates of each phase, firstly the relationship between the superficial mixture velocity and pipe vibration were obtained for different flow conditions. The root mean square (RMS) and the standard deviation were calculated from the pipe acceleration data and correlated to the mixture superficial velocity of air and water for various flow conditions. Each test was performed with a different volume fraction that was kept constant while varying the mixture superficial velocity. Piping vibration was observed to increase with flow velocity. The results present a strong correlation between the RMS acceleration and the mixture velocity; however, to obtain the volumetric flow rates of air and water it would be necessary to determine the volume fraction of the phases. Although procedures developed to measure the volume fraction could be used, a method also based on the pipe vibration response to determine the volume fractions was investigated in this work. The proposed method is based on the analysis of frequency response functions (FRFs) of the two-phase flow conveying pipe. Figure 2 show the experimental set up used to obtain the pipe FRFs.

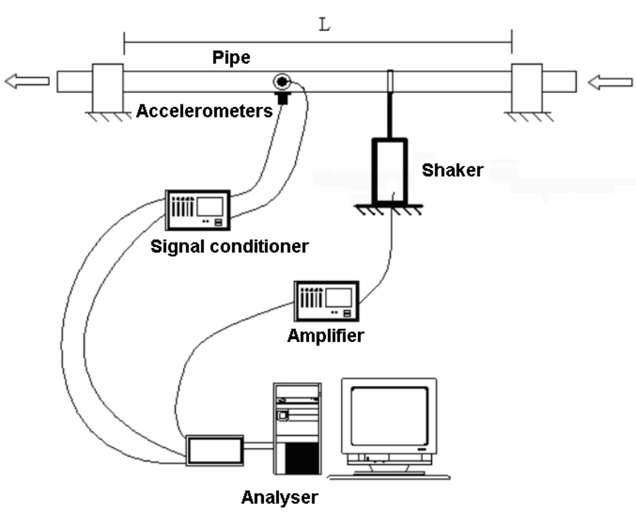

Fig. 2. Experimental set up to obtain the pipe frequency response functions.

The preliminary experiments were performed in a straight pipe 500 mm length clamped in both ends, placed in the horizontal position and submitted to different flow conditions. Diameters and material of the pipe are the same of the pipe used in the preceding experiments. The pipe was excited by a random force in the range of 0 to 1000 Hz applied by an electromagnetic actuator. Pipe vibration response in the vertical and horizontal directions was measured with accelerometers. A dynamic signal analyzer was used to obtain the averaged frequency response function of the accelerometers signal. The pipe frequency response was measure for the pipe conveying the two-phase flow with volume fractions varying from 0 to 100%, i.e., the conditions of single phase of water and single phase of air were also employed

4. RESULTS

For a given volume fractions of liquid and gas it was observed that the acceleration increases with the mixture superficial velocity in a quadratic manner. Second order polynomials were fitted to the experimental data obtained in the tests. An equation relating the RMS pipe acceleration with the two-phase mixture superficial velocity was obtained for various volume fractions of air and water. Figure 3 shows the variation of the out of plane RMS acceleration in function of the mixture superficial velocity for different volume fractions of air.

Note in Fig. 3 that if one knows the volumetric fraction, the superficial velocity can be determined and consequently the volumetric flow rates

The volumetric fractions of liquid and air were determined by analyzing the pipe FRFs. For example, Fig. 4 shows the variation of pipe natural frequency in function of air volumetric fraction.

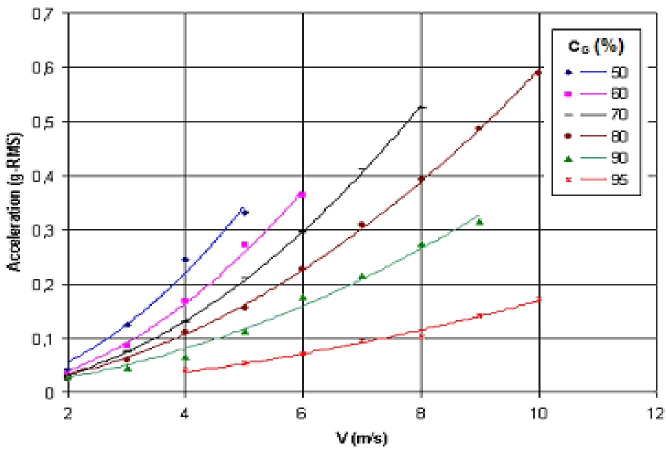

Fig. 3. In-plane RMS acceleration in function of mixture velocity for different volume fractions of air.

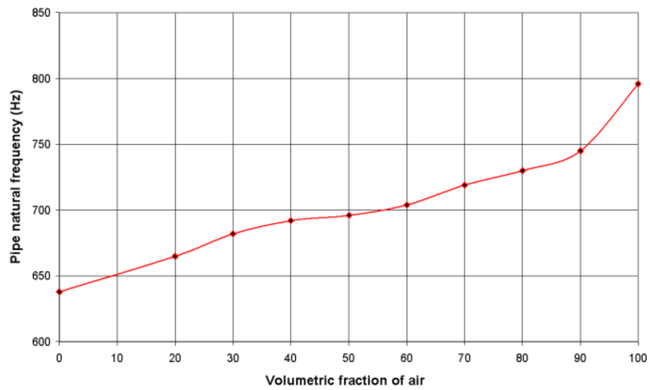

Fig. 4. Variation of pipe natural frequency in function of air volumetric fraction.

5. CONCLUSIONS

A methodology for the measurement of two-phase flow rates based on the piping vibration response was presented and demonstrated. Results of a preliminary experimental investigation on the relationship between the pipe RMS acceleration and the mixture superficial velocity showed a strong correlation with a quadratic behavior. A method for the measurement of volume fraction based on the variation of pipe natural frequencies was also verified.

REFERENCES

[1] A. L. Gama, L.R.S. Ferreira, P. H. A. Walter Filho, ”‘Experimental Study on the Measurement of Two-phse flow rate Using Pipe Vibration”, Proceedings of 20th International Congress of Mechanical Engineering, COBEM 2009, November 15-20, 2009, Gramado, RS, Brazil.

[2] R. A. Merini, A. L. Gama, Y. B. Bastos, P. H. A. Walter Filho, “G. M. Rocha, A. Q. L. Sousa, L. M. Ogino, E. Toth, “Medição de Frações Volumétricas de Escoamentos Bifásicos baseada em Análise de Vibrações”, Proceedings of the VI National Congress of Mechanical Engineering. August 18 – 21, 2010 – Campina Grande – Paraíba – Brazil.