Numerical and experimental visualization of two-phase flow in the horizontal pipe

NUMERICAL AND EXPERIMENTAL VISUALIZATION OF TWO-PHASE FLOW IN THE HORIZONTAL PIPE

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Other keywords: slug flow, horizontal pipe

ABSTRACT: *Two-phase flow in the horizontal pipe has many flow regimes. As a result, the identification of two-phase flow regime is necessary to understand the flow physics of two-phase flow. In this paper, the experimental and numerical methods are used for studying the characteristics of two-phase flow. Ultrasonic Doppler velocimetry(UDV) method was used for the velocity measurement. This experimental result was compared with that in the numerical study for ensuring the validity. The results from Both methods were quantitatively similar. This means that UVP is a useful method to study two-phase flow experimentally.*

1 Introduction

Study of two-phase flow in a horizontal pipe is important in many engineering applications. In order to deeply understanding the characteristics, several advanced method techniques, such as Particle Image Velocity [1] and laser Doppler anemometry [2], have been used to measure the two-phase flow quantitatively. Recently, some quantitative flow measurement studies using ultrasound Doppler method were presented. They showed the ultrasonic detection of moving interfaces in gas-liquid two-phase flow [3] and measurement of velocity and turbulence in turbulent pipe flow [4]. However, the results are limited to specific flow regime and the velocity results of both phase show uncertainty because of poor accuracy.

In this study, we used ultrasonic Doppler velocimetry (UDV) method to quantify the two-phase flow. The principle of the UDV method is to use the pulsed echo technique of ultrasound and to detect the echo signal of the ultrasonic wave reflected by the moving particles in the fluid. Which was first successfully confirmed and tried in experiments by Takeda [5]. According to calculating the time delay between emission of ultrasound pulse and reception of the corresponding echo signal, we can also determine the position. Compared to other techniques such as PIV or LDA, UDV has the advantages of relatively long line measurement. The spatiotemporal information about velocity fields also can be easily achieved with UDV method.

Besides, we tried using CFD method combined with volume of fluid (VOF) model to do the numerical analysis of two-phase flow to compare with the results of UDV method.

We believe this can be helpful to validate the new experimental and numerical methods of two-phase flow and better understand the physics of two-phase flow.

2 Method

2.1 Experimental method

We built the horizontal two-phase pipe flow system for the experiments. The test facility is shown in Fig.1. The length and diameter of pipe is L=9.5 m, D=0.051 m respectively. And our gas and liquid superficial velocities are set as 0.45m/s and 0.48m/s, which is suitable for getting slug flow according to our qualitative visualization tests.

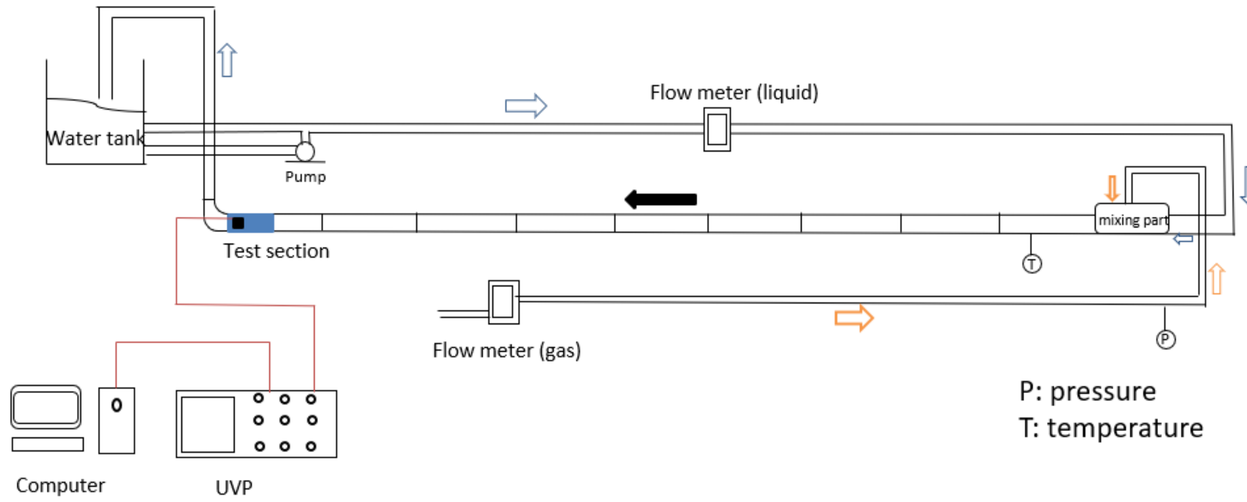

Fig. 1. Schematic diagram of experimental apparatus

The ultrasound transducer is located inside the pipe and near the output location. Compared with previous study, our transducer is directly contacted with flow. This means the reduction of ultrasonic power can be avoided, which occurs when ultrasonic beams go through pipe wall. According to this UDV system (Fig.2), we can get the long line data of velocity information from the liquid part of two-phase flow and deduce the relationship between the consecutive slug flow.

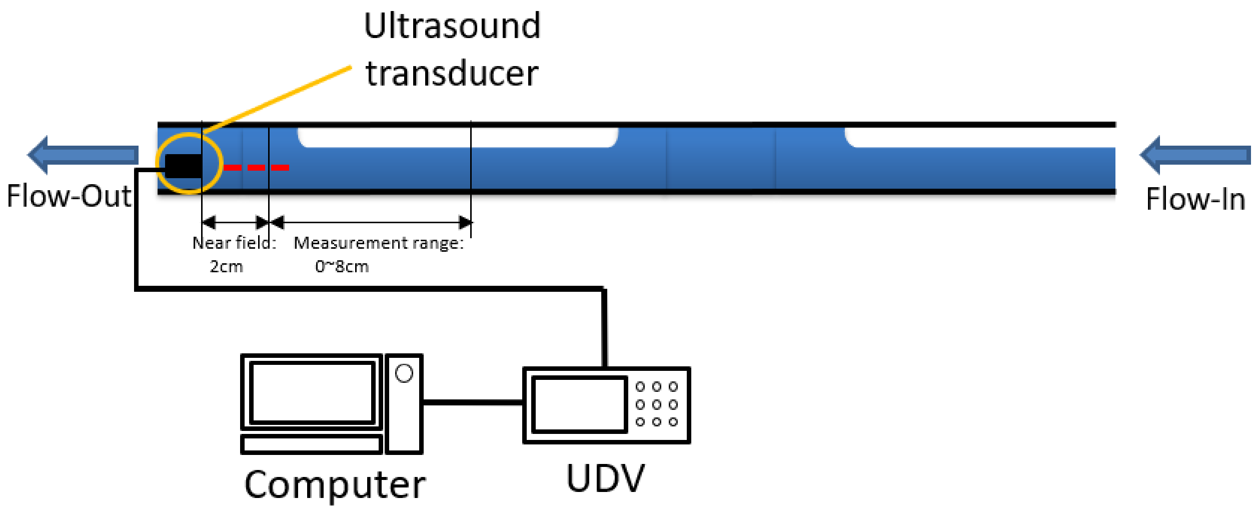

Fig. 2. Schematic diagram of UDV system

2.2 Numerical method

We used commercial CFD software for numerically visualizing two-phase flow in a horizontal pipe. VOF model which based on a fixed Eulerian computational mesh was used [6]. The numerical simulations were carried out using the same geometry with the experimental model which has the diameter D=0.051 m and length L=9.5 m(Fig.3).

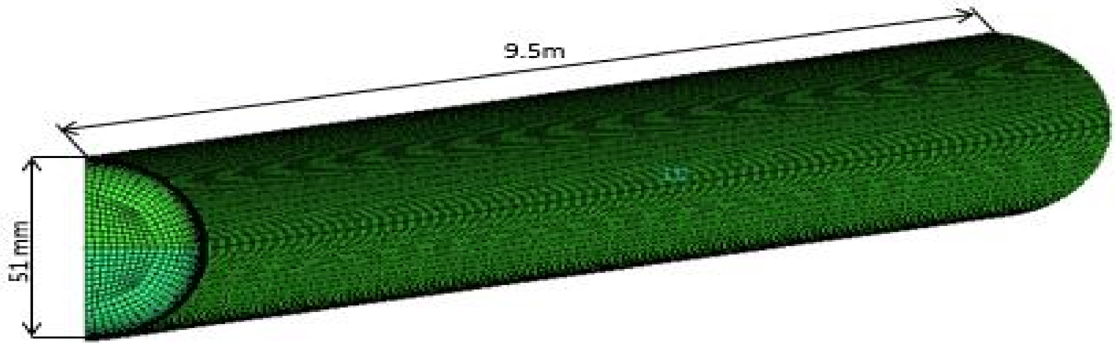

Fig. 3. Numerical mesh model

3 Results

3.1 Experimental results

According to the ultrasonic Doppler method, we clearly detect the slug flow(Fig.4). And the velocity graph is shown as Fig.5. According to which, the velocity of slug flow can be roughly calculated.

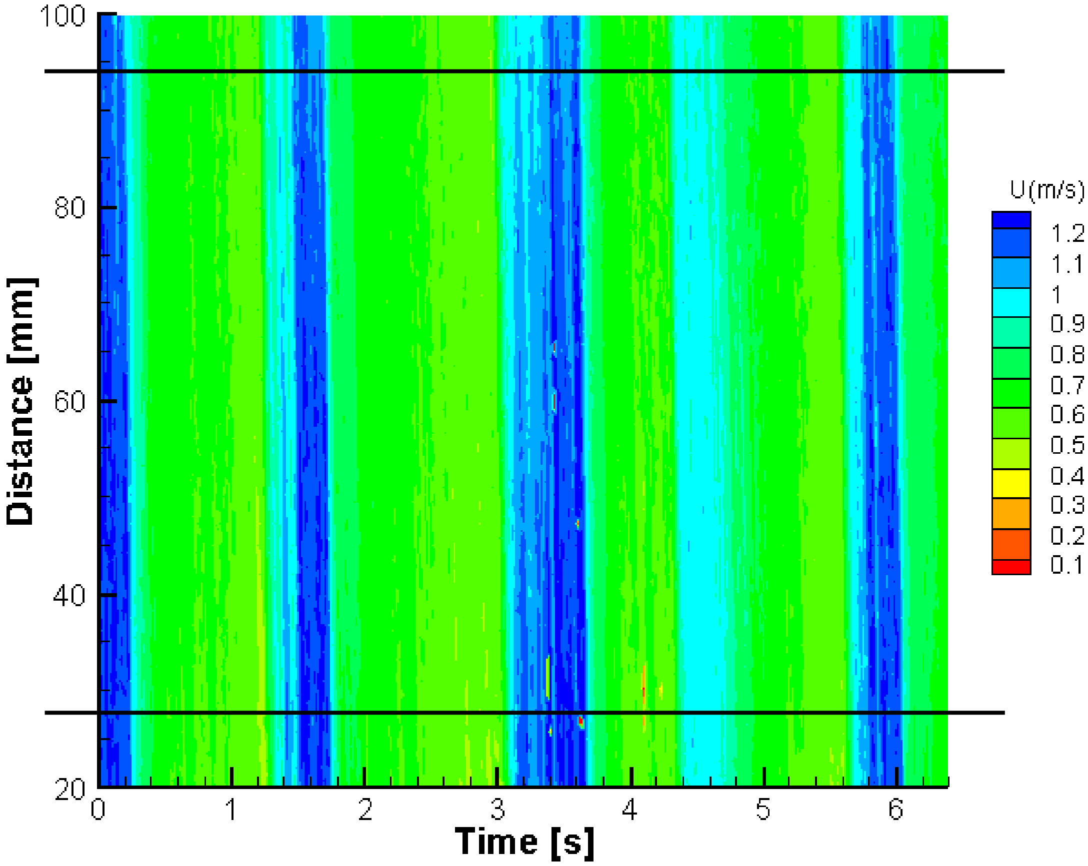

Fig. 4. The velocity contour of slug flow in UDV

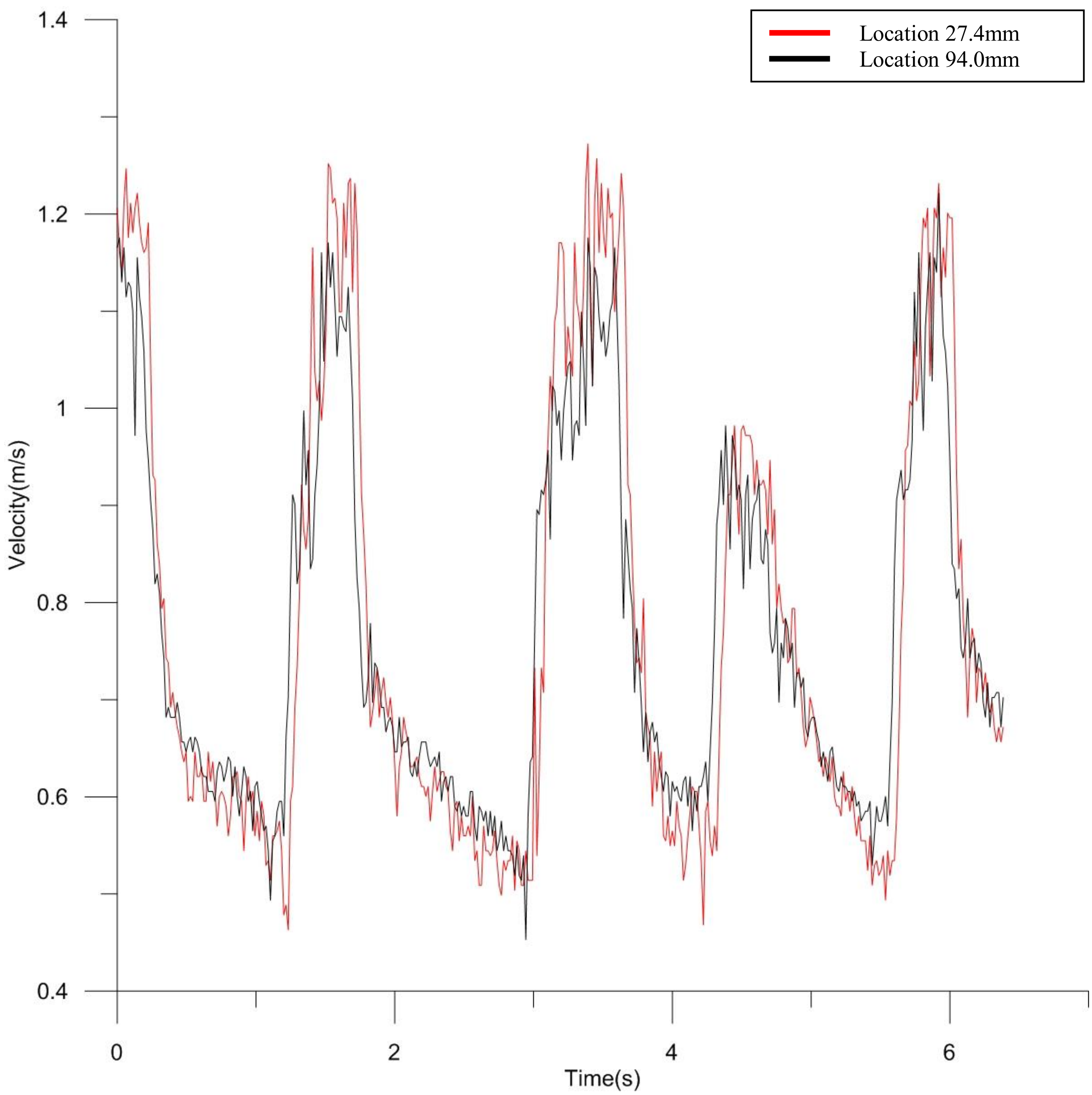

Fig. 5. The velocity graph of location 27.4mm and location 94.0mm

When the time resolutions increase(Fig.7), we can more easily find movement of slug flow compared with low resolution condition(Fig.6).

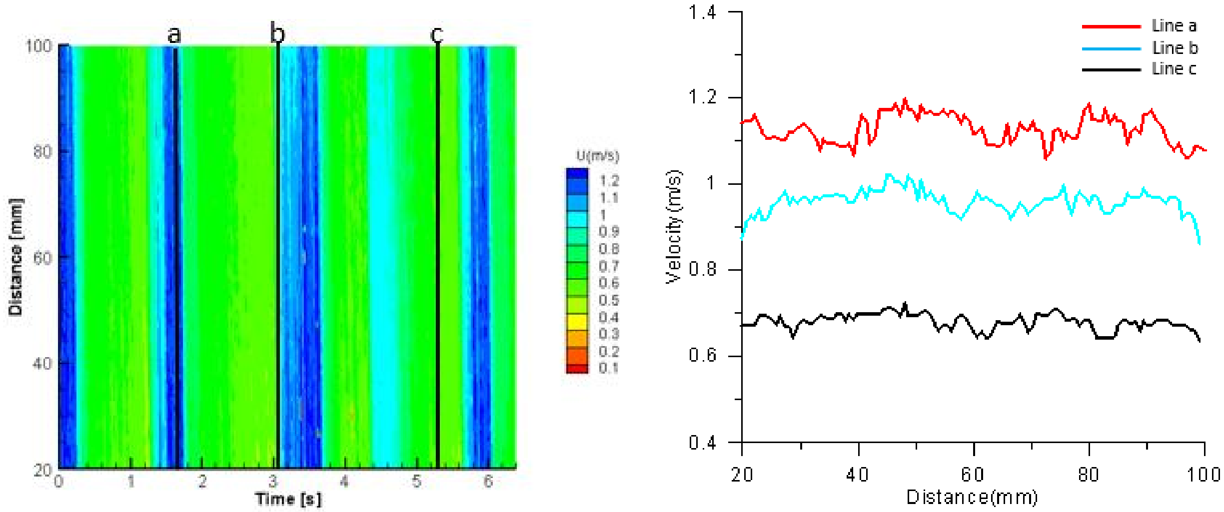

Fig. 6. Velocity contour under low temporal resolutions

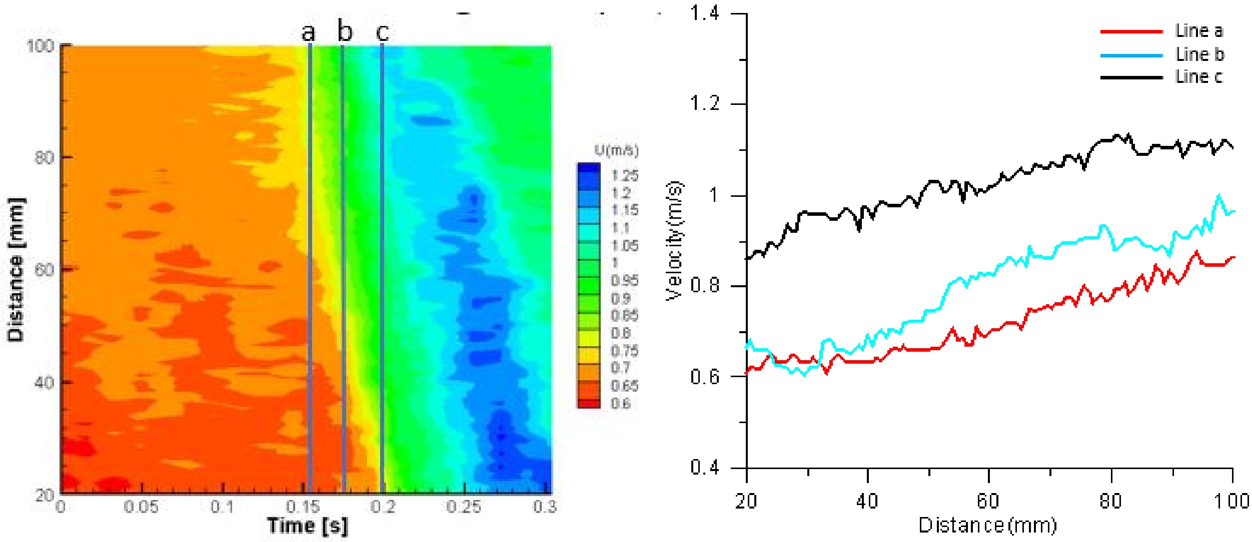

Fig. 7. Velocity contour under high temporal resolutions

3.2 Numerical results

When the superficial velocity of water equal to 0.48m/s and the gas velocity equal to 0.45m/s, the slug flow appears in numerical horizontal pipe. The slug nose and tail can be easily seen in the Fig. 8.

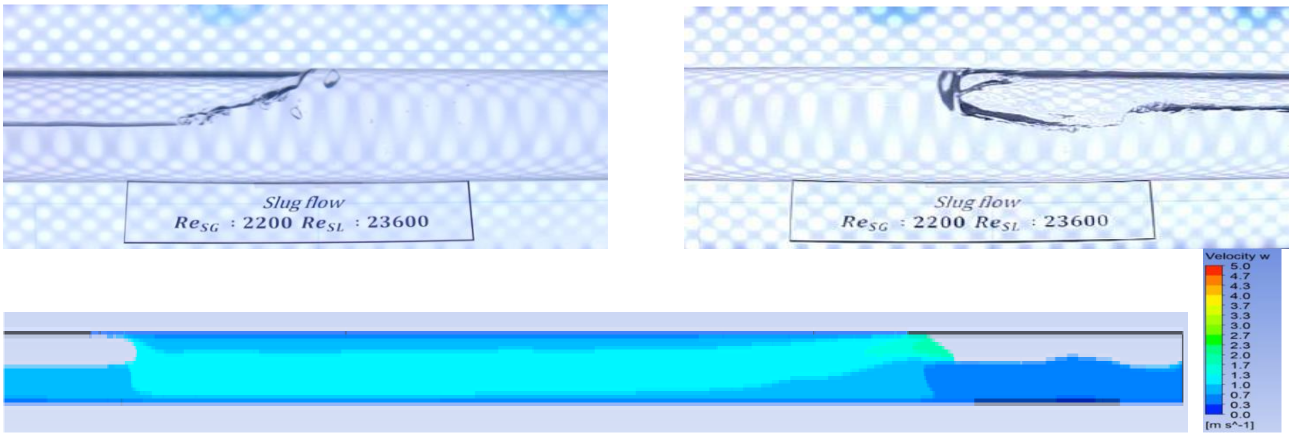

Fig. 8. The qualitative visualization of slug flow in CFD

4 Conclusion

In this study, we qualitatively and quantitatively investigated two-phase flow in a horizontal pipe system by using UDV and CFD methods. With the UDV measurement and compared with numerical results, we can see the close similarity between both methods.

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