MULTIPHASE FLOW VISUALIZATION UTILIZING PARTICLE IMAGE VELOCIMETRY (PIV)

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This article describes some advancement made in utilizing Particle Image Velocimetry (PIV) techniques in the studies of multiphase flows. A methodology that allows for velocity field measurements of both components of a two-phase bubbly flow is presented. The bubble shape is also constructed via a shadow imaging technique combined with the PIV.

INTRODUCTION

Two-phase bubbly flows are widely applied in engineering and environmental processes. The interaction of the dispersed phase with the continuous phase has a great effect on transfer processes between the phases. The relative velocities between the phases and the interfacial area and the shape of the dispersed phase are the key dependent parameters in the drag, heat and mass transfer between the phases. Although the physical understanding of bubbles rising in a liquid is a significant practical importance in many areas of engineering, neither the interactions between bubbles in clusters nor the bubble-induced pseudo-turbulence (i.e., the generation of velocity fluctuations by bubbles and their wakes in a laminar flow) are fully understood. Modeling bubbly flows with the Computational Fluid Dynamics (CFD) codes requires detailed information about the full field velocity close to the bubble and its wake. Such information is not widely available.

METHODOLOGY

Most methods developed for velocity measurements can be classified into two categories: optical methods and opaque methods. Optical methods such as Laser Doppler Velocimetry (LDV) and Pulsed Laser Velocimetry (PLV) can be applied to two-phase flows when the particle sizes are small with low concentrations. For the case of opaque materials, Magnetic Resonance Imaging (MRI), Neutron Radiography Imaging (NRI), Gamma ray and X-ray methods are examples of non-invasive measurement tools can be used in certain flow situations. Ultrasonic Resonance is also utilized for flow regime and velocity determination. Modern developments in image processing and advances in power computing have been responsible for the use of flow visualization to obtain quantitative velocity data with accuracy. PIV is one of several tools, which were developed over the past decade and applied for various fluid applications. In this study, a PIV setup for capturing simultaneously, the liquid velocity vector field and bubble trajectories in circular ducts with laminar and turbulent flows is being developed.

The application of PIV has been increasingly successful in this decade. PIV provides instantaneous velocity fields in a 2-D plane [1]. It can be applied to study two-phase flows if the component phases can be separated during analysis [2-6]. With the recent improvement of digital imaging technology , PIV measurement techniques are now capable of capturing high-resolution digital images of gas/liquid two-phase flows, in which the continuous liquid phase and the dispersed gas phase are unsteady and multi-dimensional.

SOME RESULTS

Measurements can be performed to capture the effects of rising air bubbles on the continuous liquid phase. For two-phase flow, the upper scale for velocity is approximately the velocity of the gas phase. As the gas passes through the continuous liquid, it drags liquid in the vicinity of the bubble and accelerates the liquid to approximately the velocity of the bubble. Figure 1 represents the results of the vorticity ω_y on X-Z plane, position y=0, at t=33.3 ms after the bubble has entered the viewing volume and for bubble trajectory within the bubble center. The plot of the vorticity ω_z on X-Y plane, position z=0.61, at t=33.3 ms after the bubble has entered the viewing volume and for bubble trajectory through the pie center.

CONCLUSIONS

PIV is a powerful tool to provide some understanding of the complex physical phenomena of multiphase flows. Instantaneous full-field velocity components can be estimated. A key advantage of this scheme is the ability to provide data of simultaneous velocities of the phases. These data are urgently needed to validate the Computational Fluid Dynamic (CFD) codes. However, a large number of images is needed to achieve a reasonable turbulent average quantities.

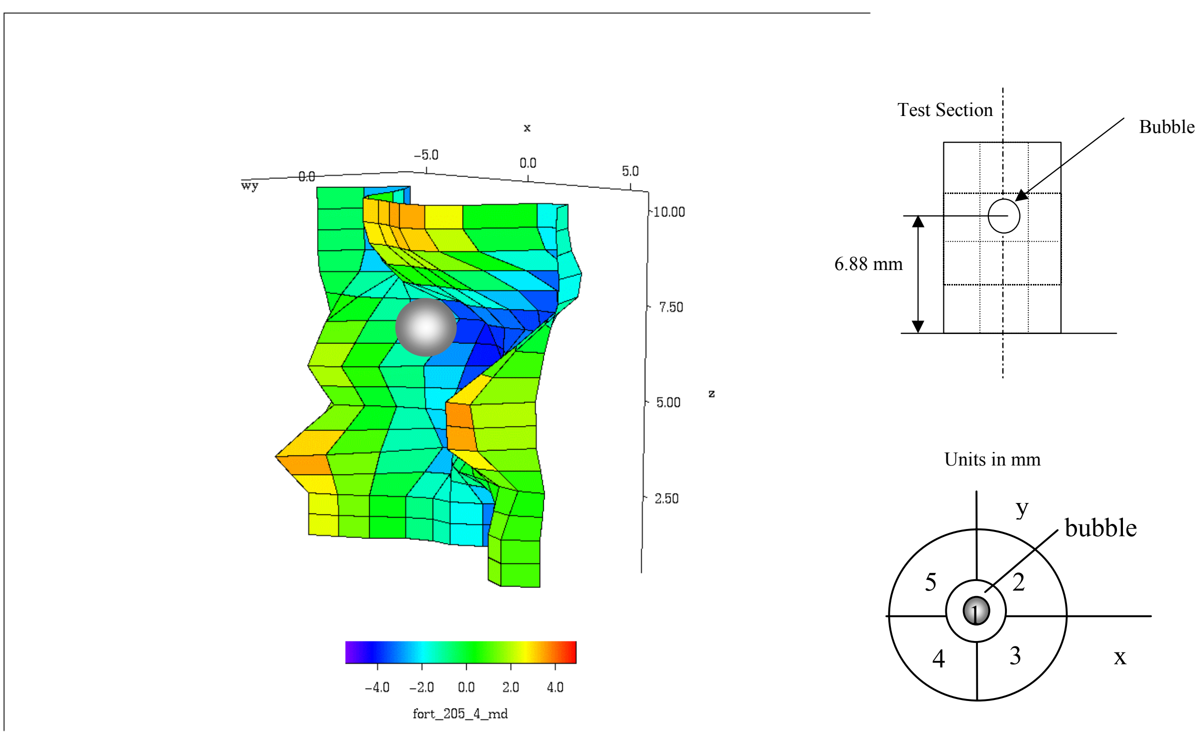

Figure 1. Surface plot of ω_y on X-Z plane, position y=0, at t=33.3 ms after the bubble has entered the viewing volume and for bubble trajectory 111.

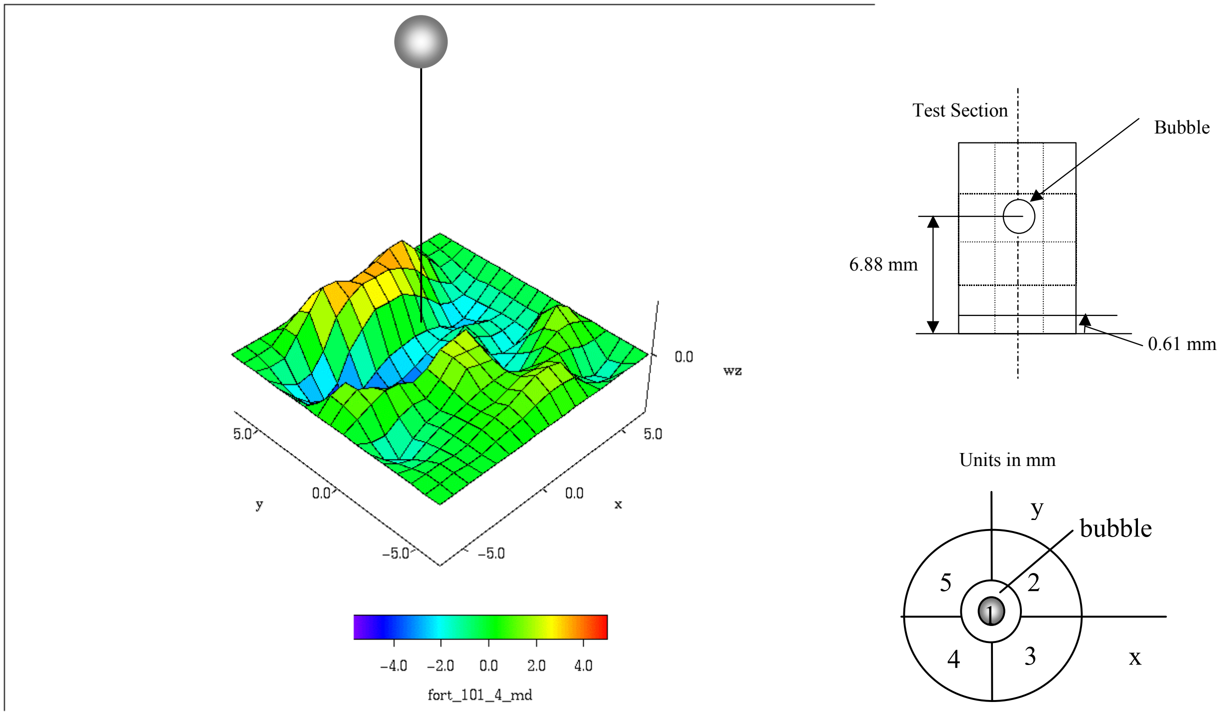

Figure 2. Surface plot of ω_z on X-Y plane, position z=0.61, at t=33.3 ms after the bubble has entered the viewing volume and for bubble trajectory 111.

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