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BUBBLE DEFORMATION AND SURROUNDING FLOW STRUCTURE MEASURED BY PIV/LIF AND SHADOW IMAGE TECHNIQUE

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ABSTRACT

The gas-liquid contactors find in broad application, such as fluidized-beds, bioreactor bubble columns and other equipment involving solid-liquid, gas-liquid and even solid-gas-liquid flows, and bubbly flow has been investigated both experimentally and numerically for many years. Some of our limitations can be attributed to the lack of understanding of the correlation between the global flow structure and local influence of interaction between the dispersed phase (bubble or solid) and the surrounding liquid phase.

Until the widespread availability of PIV, many measurement method using image-processing techniques were applied to bubbly flow [1][2]. To investigate the flow in the vicinity of the bubble, authors' group has developed a particular PIV technique with fluorescent tracer particles [3][4]. With this measurement system, we have been able to study the localized phenomena, such as the surrounding wake structure and the factors influencing the forces on the bubble; that is, the interaction between gas/liquid phases and the associated transfer mechanisms. In particular, to understand the bubble transfer mechanisms experimentally, it is necessary to associate the flow structure with the actual three-dimensional bubble behavior. Therefore, during the course of the development of image processing techniques, several experimental groups have developed methods to investigate three-dimensional bubble behavior [5][6][7].

The objective of the present study is to obtain fundamental knowledge of the translational motion of the bubble, as caused by the interaction between the linear shear flow field and the rising bubble within it. Fig.1 shows the experimental apparatus. We explored the flow structure in the vicinity of the bubble in one plane and its deformation in two planes respectively by PIV/LIF and a projection technique in two perpendicular planes. For our experiment, we chose a single air bubble with an equivalent diameter D_e=2~6mm, rising in a shear flow field set at 2.0s^{-1} of shear rate. By reconstructing the instantaneous three-dimensional bubble shapes from two perpendicular planar images, we estimated three-dimensional bubble trajectory and the interactive influence on flow structure with consideration of the three-dimensional arrangement.

Fig.2 shows approximated three-dimensional deformed bubble shape and corresponding vorticity contour. We quantitatively showed the three-dimensional wake structure, viewed in terms of the vorticity, with additional consideration given to the relative arrangement and approximated three-dimensional shape and trajectory of the bubble. Bubble oscillated to a characteristic moment in *y*-direction mainly. As shown in Fig.2(c), the bubble moves across the laser sheet in *x*-*z* plane. According to the side view of bubble trajectory, bubble moves toward the direction where *x* increases and *y* decreases. At the position A, the region with relatively high intensity of vorticity appeared at left edge of the bubble while the region with high intensity of vorticity exists at lower right of the bubble at position B. This transition can be explained by

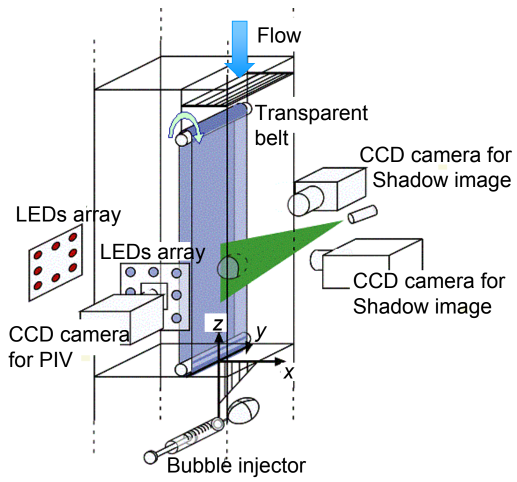

FIG.1 SCHEMATIC OF EXPERIMENTAL APPARATUS.

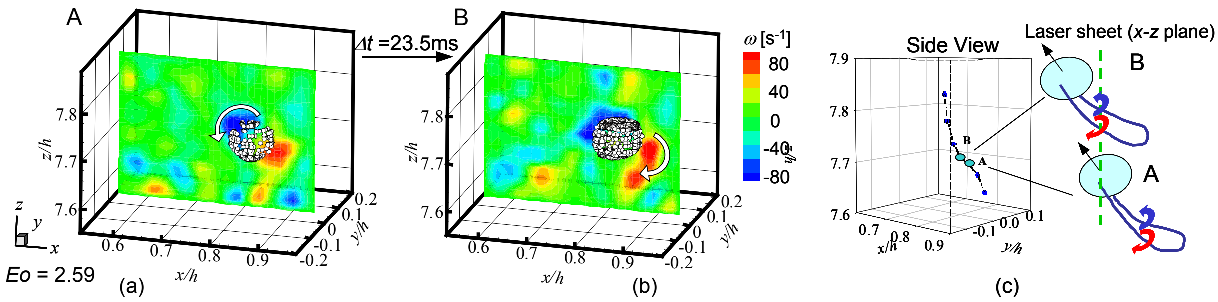

FIG.2 THREE DIMANSIONAL BUBBLE SHAPE AND CORRESPODING FLOW STRUCTURE,
(a) Instantaneous Bubble Shape and Vorticity Contour at Position A,
(b) Instantaneous Bubble Shape and Vorticity Contour at Position B,
(c) Three Dimensional Bubble Trajectory (Side View).

the three-dimensional structure of bubble's wake.

In order to elucidate the effect of bubble deformation on the wake structure behind the bubble, the relation between aspect ratio As and the parameter of asymmetric property R_l is shown in Fig.3(a). The large R_l indicate large curvature of right-hand-side edge and R_l=0.5 indicate symmetric shape. Fig.3(c) shows the relation between bubble trajectory and the vorticity near the right-hand-side edge of the bubble ω_r. With consideration of the vorticity ω_r estimated from PIV data respectively, we elucidated that bubble asymmetric deformation was induced by the growth of the hairpin vortex attached to the bubble's edge. The bubble indicated remarkable asymmetric deformation with maximum value of the vorticity on the bubble's edge. The bubble then shed the vortex downstream, and its lateral motion switched to the opposite direction as shown in Fig.3(b).

In conclusion, we associated lateral transition of bubble zig-zag motion with periodical bubble deformation and wake structure, using PIV/LIF/double-shadow projection technique. The growth of vortex on the edge of the bubble induced asymmetric deformation, and the bubble then changed its direction of motion after shedding vortex.

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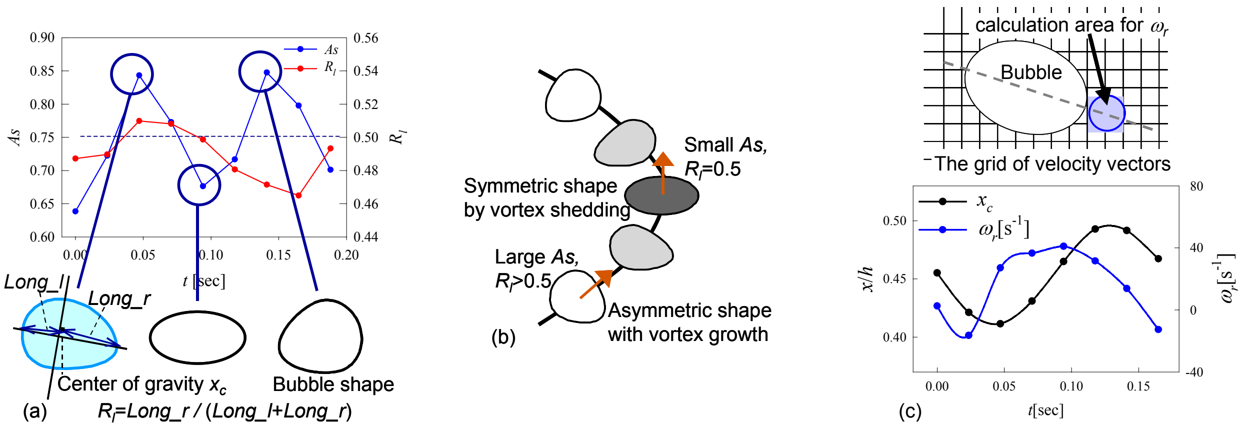

FIG.3 THE RELATION BETWEEN BUBBLE DEFORMATION AND WAKE STRUCTURE,
(a) Definition of Asymmetric Property Parameter R_l and Relation between Aspect Ratio As and R_l,
(b) Schematic of Deformed Bubble Motion, (c) Relation between x_c/h and ω_r.