DEVELOPMENT OF MULTI-LAYER LASER-SCANNING PIV AND APPLICATIONS TO HYDRAULIC ENGINEERING

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Two or three cameras are generally used for 3-D visualization techniques in air or water flows. However, it is difficult to set up the instruments accurately and determine many camera parameters in PIV/PTV. To avoid complicated settings of optical devices, some researchers investigated 3-D measurements using a single camera and specially designed illumination techniques. For example, Ushijima & Tanaka(1996) developed a 3-D PTV system, in which a scanning laser-light sheet was generated from a pair of optical scanners.

Therefore, in this study, a multi-layer scanning 3-D PIV system was developed, in which different elevated laser light sheets were projected into the water flume almost simultaneously using a specially-designed rotation instrument. This multi-layer scanning PIV system is able to measure instantaneous velocity components in all three dimensional volumes at the same time. Furthermore, the other perpendicular velocity component can also be evaluated by using the continuity equation from the velocity components in a picture.The present PIV system was applied to an open-channel flow over a mound bed with rising and falling slope sections, in which an upward flow is generated due to change of channel geometry. In order to examine the accuracy of this sheet-scanning PIV method, these PIV results were compared with the data measured by a laser Doppler anemometer(LDA), and it was recognized that the measured data of the present PIV was in good agreement with LDA data.

The experiments were conducted in a 10m long, 40cm wide and 30cm deep tilting flume, as shown in Fig.1. In order to generate strong upward flows, a triangle-shaped mound, which consisted of a rising and falling slopes, was attached on the channel bed. This triangle-shaped 2-D mound size was L_x=14cm and L_y=7cm as shown in Fig.1. H is the water depth and $h \equiv H - L_y$ is the vertical position from the top-edge of the mound. The coordinate x is the streamwise direction, y is the vertical and z is the spanwise directions.

The time- averaged velocity components in each direction are defined as U, V and W, and the corresponding instantaneous velocity components are as $\tilde{u}$, $\tilde{v}$ and $\tilde{w}$, respectively. Four kinds of laser light sheets(LLS) were projected over the triangle-shaped mound as mentioned later. The thickness of each LLS, Δy, was 2mm in the present laser beams. The high-speed CCD camera was placed over the water flow. In this specially-designed beam-rotation instrument, four laser sheets that have different adjustable elevations were projected into the tilting flume by using a rotating beam splitter which was developed originally in our laboratory. This beam splitter has four arms included with adjustable plane mirrors. 2W Ar-ion laser light was projected into the flume at four different elevations of

LLS in the same time. The speed of the beam rotation was 20Hz, and thus the time lag of the neighboring LLS was $1/4 \times 20 \cong 0.0125$ sec

The seeding particles, which have a diameter of 100 μ m and are made of Nylon 12 (specific density is 1.01), were uniformly scattered in the circulating water of the flume. The distance Δy between the neighboring LLSs was all adjusted accurately as $\Delta y = 2$mm (Fig.1). The digital images on the horizontal planes at different elevations were taken simultaneously by making use of a high-speed CCD camera of 250Hz per one frame which was placed above the free surface. As the results, a 3-D flow volume, in which LLS were projected, was measured by the PIV algorithm. When more laser light sheets are splitted and projected, a more detailed information of 3-D PIV is available; the maximum number of the beam splitters was able to set 16 in the present system.

Fig.2(a) shows the downstream profiles of time-averaged streamwise velocity $U(x)$ at the position of $y = 38$ mm and $z = 0$. In order to examine the accuracy of the present PIV, the same flow was measured with a two-component laser Doppler anemometer(LDA). In this figure, the value of U increases gradually before mound summit and attains almost constant in the zone of $x > 0$. Fig.2(b) shows the downstream profiles of time-averaged vertical velocity $V(x)$ along the channel center of $z = 0$ at the positions of $y = 32$ mm, respectively. $V(x)$ was evaluated by the continuity equation and free surface contition of $V(x) = 0$ at $y = h$. It is judged that the present PIV data are in good agreement with LDA data. It is therefore concluded that the present LLS-scanning PIV system has highly accuracy in not only in-plane velocity measurements of $(\tilde{u}, \tilde{v})$ but also the vertival component of $\tilde{v}$.

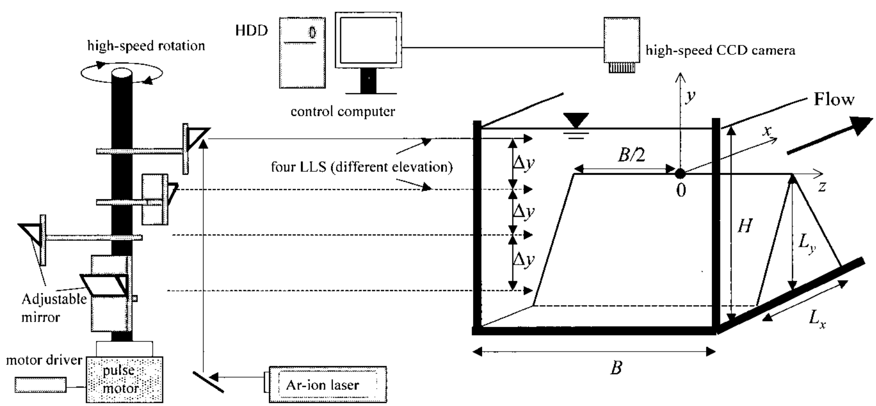

Fig. 1 Experimental setup.

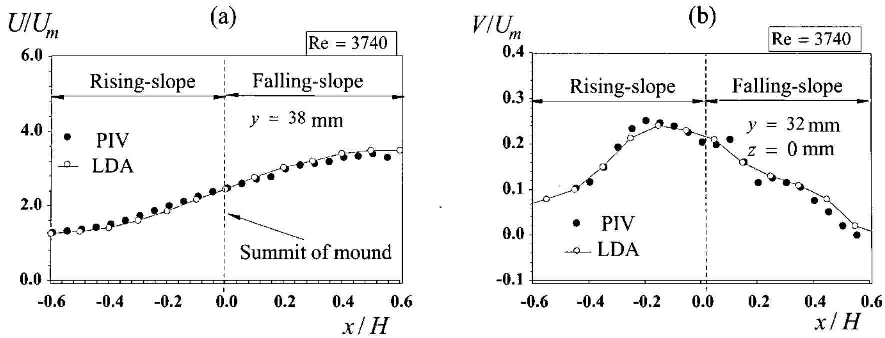

Fig. 2 Comparison of primary and vertical velocities with LDA Ushijima, S. and Tanaka, N., 1996. Three-dimensional particle tracking velocimetry with laser-light sheet scannings, Trans. of the ASME, Vol.118, pp.352-357.