Streak Image Based 3D Tomographic Velocimetry applied to a Water Flow past a Submerged Square Cylinder

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In the present paper, the authors propose a novel technique in 3D tomographic PIV where the particle images are recorded with continuous and pulse laser light, and CCD cameras with single short exposure time to reproduce 3D particle streak images instead of conventional point images recorded with two short laser pulses. Compared to conventional tomographic PIV, this new approach has several advantages: cameras do not require optional double exposure mode, continuous laser source can be used and focusing of particle image is not so severely required for successful velocity recovery (Ohmi et al. 2013). Moreover, the ghost particles are less generated and if any, can be filtered out more easily. On the other hand, high image processing computational load for 3D image reconstruction because of need of proper extraction of 3D voxel blobs corresponding to individual particle paths from the reconstructed voxel intensity space, and the intersection of particle paths and directional ambiguity on the camera projected images are some of the challenges to overcome. Presently, the authors attempt to devise new ways to refine this new streak based tomographic image velocimetry technique and apply it to the measurement of a 3D water flow past a finite-height submerged square cylinder.

Experimental Method and Results

The experiment is carried out in a small laboratory size circulating water channel. The test section of the channel is 175 x 175 mm in cross section and 900 mm in length. The submerged test square cylinder is 15 x 15 mm in cross section and 87.5 mm in length, which corresponds to half the height of test section, and is fixed vertically on the bottom plane of the channel.

Four cameras, two at the top and two at the bottom are used to capture the streak images of the particles flowing past the submerged square cylinder. A continuous laser light is used to illuminate the particles while a pulse laser light fired at the beginning of the synchronizing pulse highlights the start of the particle streak. The camera and the pulse laser are both externally triggered synchronously using an external source. The exposure time of the camera is wisely chosen to obtain suitable particle streak length.

Fig.1 shows a sample instantaneous 3D velocity distribution in a vertical cross section obtained by this novel tomographic image velocimetry. In this figure the left plot represents the tomographic reconstruction results of 3D particle paths obtained by the dynamic threshold binarization algorithm (Ohmi et al. 2000), from which the particle displacement data of the right plot are calculated. In these figures, the thickness of the reconstructed volume is 10 mm, while the thickness of the actual laser light sheet in the water channel is 15 mm. Since this is just one shot of instantaneous tomographic PIV, results and the velocity is not phase averaged, statistical features of the 3D flow down wake of the square cylinder are not clearly depicted. Still this shows overall 3D spatial (but only partial) structure of von Kármán vortices swept away from the top end of the square cylinder.

References


(a) Tomographic reconstruction of 3D particle paths

(b) 3D vector plot

Fig. 1 Tomographic PIV results of the flow past a finite-height submerged square cylinder.