VOLUMETRIC MEASURMENTS ON A PROPELLER IN A CAVITATION WATER CHANNEL

tsi.com

APPLICATION NOTE V3V-FLEX-012 (US)

Introduction

A study was conducted in the West Japan Fluid Engineering Laboratory Co., Ltd. closed return cavitation water channel with a test section of 500 × 500 × 2000 mm of the flow downstream of a five-bladed, powered aquatic propeller at a freestream velocity of 4.0 m/s. A V3V-Flex volumetric measurement system with four 4 megapixel cameras was used in order to provide high-resolution instantaneous and phase-averaged volumetric measurements.

Experimental Setup

The experimental setup consisted of four 4MP-LS cameras (Model #630090) fitted with Scheimpflug mounts and 60 mm lenses. The cameras were arranged in a linear array and focused on the measurement volume with a nominal magnification of 0.085. The incidence angle between the outermost cameras was 57 degrees. The large angle between cameras increases the accuracy in the span-wise direction (*z*-coordinate), but also increases the image distortion associated with imaging at a large angle through different media. Therefore, 30 degree, water-filled prisms were used to substantially decrease or eliminate the image distortions. The prisms were positioned so that the viewing angle of the camera was approximately normal to the prism surface. An external trigger from the propeller motor was used to synchronize the image capture with the phase of the blade passage. The velocity fields were phase-averaged at multiple blade locations in order to examine the tip vortex phenomena.

The seed particles were polyamide spheres (Model #10090) with mean diameter of 55 microns. A 200 mJ dual-head Nd: YAG pulsed laser was used as the illumination source which passed through a series of light sheet optics that created an illumination volume. The illuminating light then passed over a 45-degree turning mirror in order to direct the light upward through the measurement volume. The edges of the illumination volume were defined using a knife-edge beam block to precisely define the forward and rearward bounds of the measurement volume. The final measurement volume of the overlapped cameras was 140 × 95 × 65 mm.

The laser and cameras were synchronized with a Model #610036 timing box with timing precision of 250 ps. The calibration, image processing, and three-dimensional particle tracking was accomplished using INSIGHT V3V™DPIR software. The software uses dense particle identification and reconstruction (DPIR) in order to extract the volumetric velocity field from densely-seeded flows.

An image of the experimental setup during data acquisition can be seen in Figure 1.

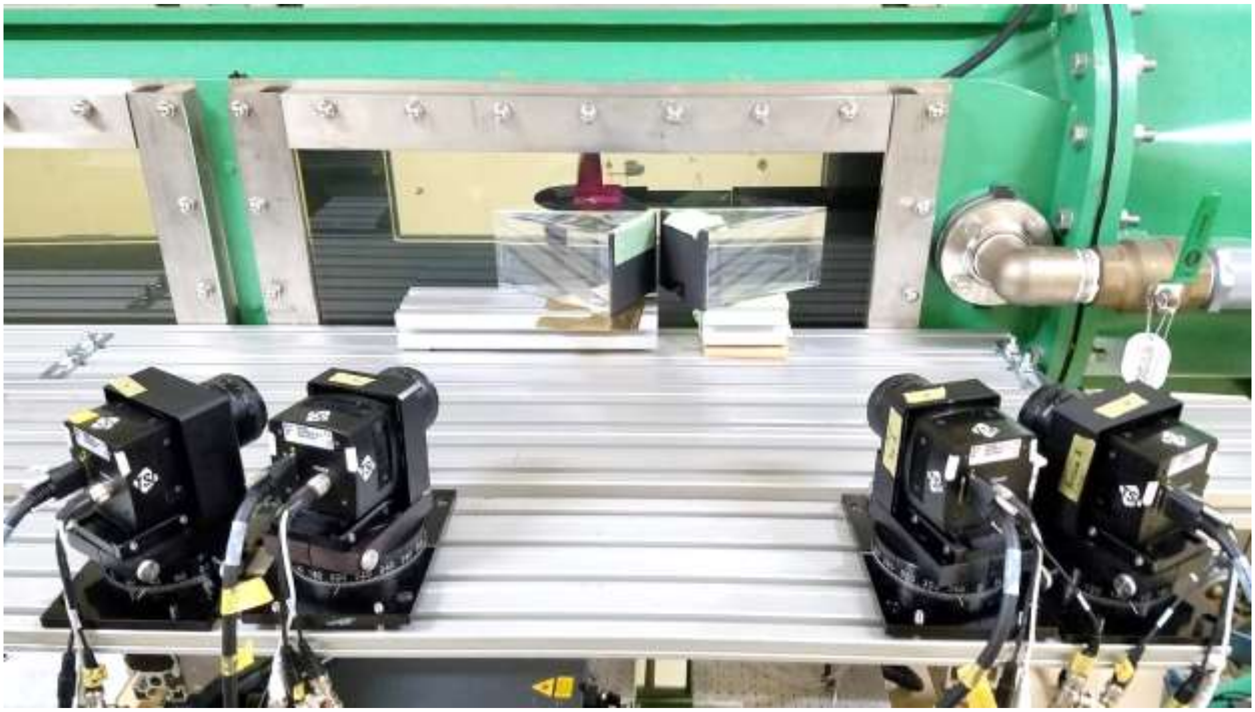

Figure 1. The experimental setup showing the location of the four 4MP-LS cameras. Water-filled prisms were used to reduce distortions associated with refractive index changes. The laser (underneath) was projected upward through the measurement volume using a 45 degree mirror.

Results

A sample result of the phase-locked measurements can be seen in Figure 2. Approximately ½ of the propeller wake has been captured. A total of 4 phases were taken, separated by 3.33ms. At each phase, 500 image sets were captured and then averaged. The slices are colored by the velocity magnitude, and the Q-criterion is identified by the red isosurface. The instantaneous realizations were remarkably similar indicating that the cycle-to-cycle variation in the flow field was minimal. In terms of large-scale phenomena, a major feature of the flow is that the thrust created by the propeller produces a higher-speed streamwise jet downstream as can be seen in the red portions of the velocity-magnitude slices. The outer part of the volume represents the freestream velocity (blue regions) which was slower than the propelled flow. The tip vortices are clearly identified by the Q-criterion isosurfaces in red. Three and a half tip vortices are seen in the plot, with no visible interaction between sequential blade tip passages.

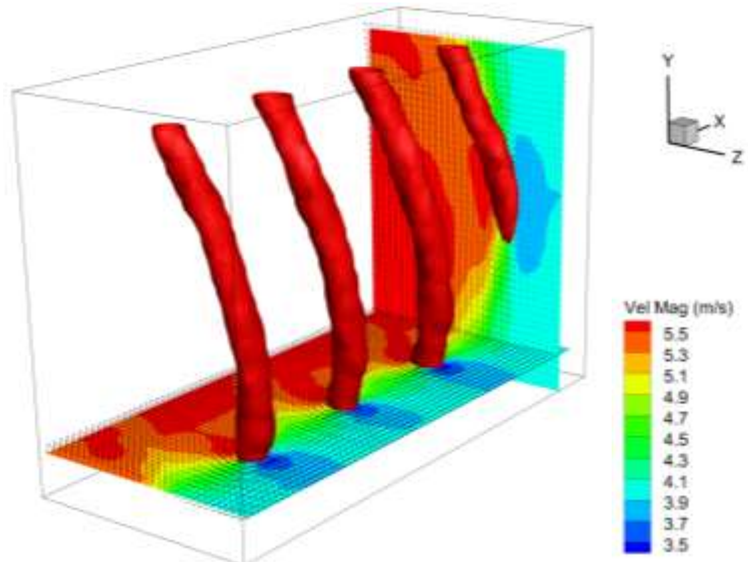

Figure 2. A phase-averaged realization of the flow field downstream of the propeller. The isosurface indicates Q-criterion (0.018 s-2).

Conclusion

The four high-resolution 4MP cameras allowed for highly accurate particle positioning which contributed to the low uncertainty in the velocity measurement. The results are useful for assessing the propeller efficiency, thrust, and general flow field characteristics. Minor changes to the propeller design can be seen in the resulting flow field imaged by the V3V system. These changes can be used to assess the next phase of propeller design. Overall, the V3V-Flex system used with 4MP cameras is an excellent tool for high spatial resolution data, especially well-suited for hydrodynamic measurements.

Test Facility and data courtesy of: West Japan Fluid Engineering Laboratory Co., Ltd, http://fel.ne.jp.

UNDERSTANDING, ACCELERATED

TSI Incorporated – Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 680 1220	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

