TIME-RESOLVED PIV MEASUREMENTS OF A HORSESHOE VORTEX

APPLICATION NOTE TRPIV-004 (US)

The Horseshoe Vortex System

Flow interactions with an object attached to a surface are present in an extremely wide variety of engineering applications. A scan of the literature reveals a plethora of flow situations, for example the scour upon bridge piers, pollution dispersion within urban canyons (Karra et al. 2011), and station holding in fishes (Carlson and Lauder, 2011). A deeper understanding of the flow phenomena is desirous in order to better address the consequences of fluid structure interactions.

The flow upstream of a wall-mounted cylinder was examined in this application note using time-resolved particle image velocimetry (TRPIV). The flow topology over a low aspect ratio, wall-mounted cylinder contains a number of interesting phenomena: the upstream horseshoe vortex system, the downstream arch vortex, the tip vortices shedding from the upper edges, and the pseudo von Karman vortex shedding present in the downstream. This type of flow has been examined previously in a number of cases, for example in Matthaeus et al. (2011).

In the current experiments, a cylinder of height/diameter ratio (h/d) equal to 0.5 was placed onto the bottom surface of a water flume with a test section of 150 × 150 × 450 mm, with Reynolds number based on cylinder diameter of ≈ 11,000. The region upstream of the wall-cylinder interface was imaged. A long exposure image, showing the path lines of the particle can be seen in Fig. 1.

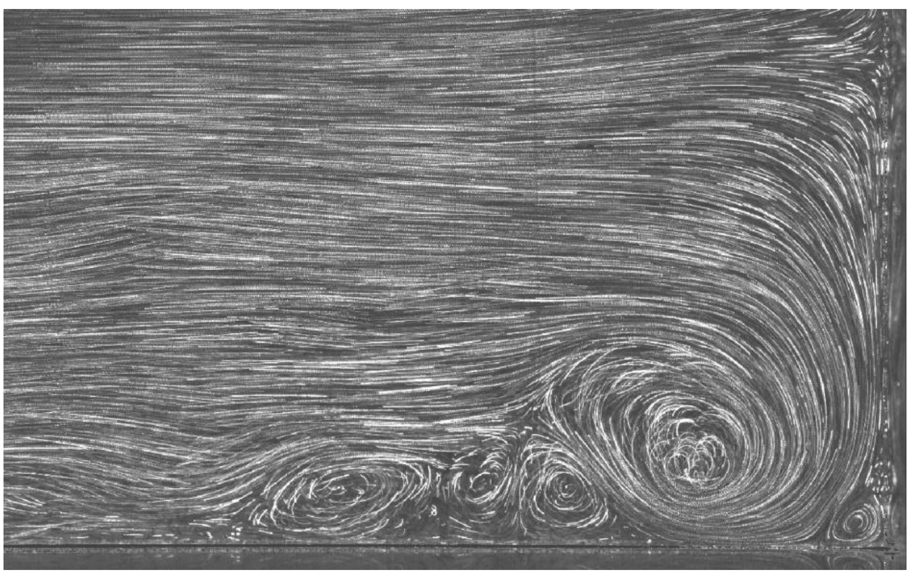

Fig. 1. This long exposure image exhibits the path lines of particles in the flow.

Experimental Setup

The time-resolved PIV system consisted of a dual-head 1000 Hz Nd:YLF pulsed laser (TSI Model# YLF10-1000-LIT) with 30 mJ/pulse and fitted with adjustable light sheet optics (Model# 610026), and a 1280 × 800 pixel CMOS camera operating at 1000 Hz (Model# 630083-3GB). The laser was positioned so that the light sheet entered the test section from below, and the camera viewed from the side. A schematic of the experimental setup can be seen in Fig. 2; flow is from left to right. The light sheet is shown in green, and the camera field of view is shown within the dashed box. The measurement region is directly upstream of the cylinder, along the coincident centerline of the test section and the cylinder.

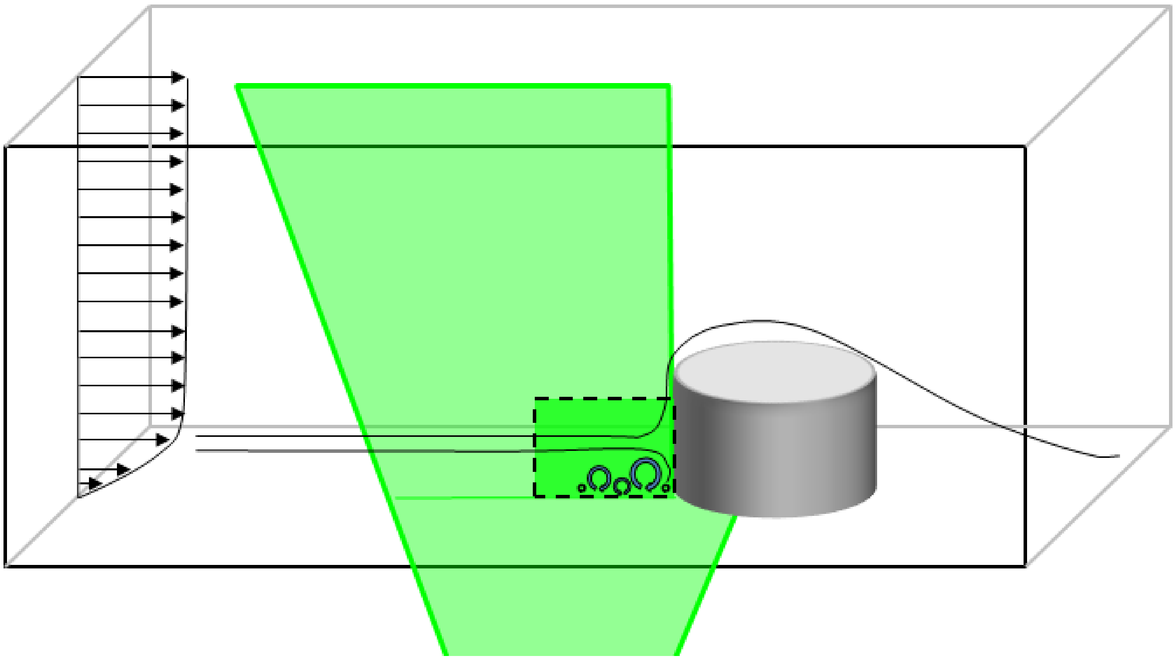

Fig. 2. Schematic representation of the experimental setup. The green represents the laser light sheet, and the dashed rectangle indicates the field of view of the camera.

Results

Several sets of results were acquired with the TRPIV system. The first was a set of flow visualization results, an example of which can be seen in fig. 1, that show several of the flow phenomena such as the stagnation point of the flow on the front face of the cylinder, and at least five (5) vortices comprising the upstream horseshoe vortex system.

The quantitative TRPIV results exhibited interesting phenomena as well. An example result of an instantaneous velocity field can be seen in fig. 3, which shows velocity vectors overlaid on a contour of vorticity. Of note are the location of the system of upstream horseshoe vortices that are clearly indicated by the vectors and vorticity contours.

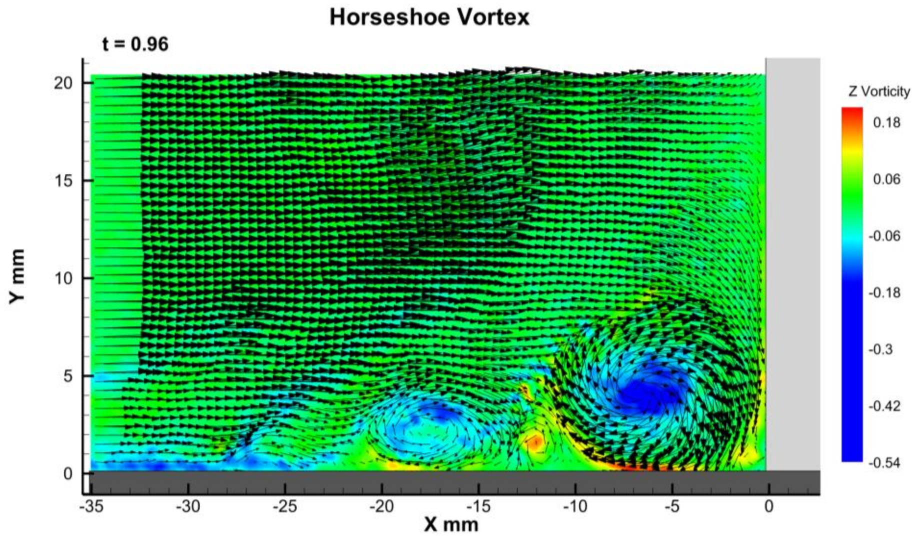

Fig. 3. Instantaneous velocity field showing a color contour of vorticity with velocity vectors overlaid. Flow is from left to right, with the bottom wall indicated in dark gray, and the location of the cylinder shown in light gray.

Summary

The upstream dynamics of a wall mounted cylinder were examined with the TSI TRPIV system. The resulting system of vortices match well with previous research on this topic.

References

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