TIME-RESOLVED PIV MEASUREMENTS OF FLOW THROUGH A FAN DUCT

APPLICATION NOTE TRPIV-001

Flow Through a Ducted Fan

The flow through a fan duct was measured using a time-resolved PIV system. Vorticity was examined along a plane intersecting the central axis of the duct. A time-trace of vorticity was plotted using the TSI time-resolved PIV toolbox.

Experimental Setup

A motor with a shaft encoder was attached to a 5-bladed fan, with the flow output directed through a transparent Plexiglas circular duct with a diameter of 140 mm, which was the same diameter as the fan blade. A photograph of the experimental fan system under investigation can be seen in Fig. 1.

Fig. 1. Photograph of the fan and duct used in the current experiment. The cover has been removed from the motor housing for clarity. The cover was in place for the experiments.

A 1 kHz dual-head Nd:YLF laser (527 nm) was positioned downstream of the duct, with the light sheet directed toward the fan. The light sheet was collinear with the central axis of the duct in the vertical plane.

The 2 kHz camera, with 1k × 1k pixel resolution, was positioned at 90 degrees to the light sheet with a 60 mm Nikor lens for a resultant magnification of 0.017. Data was captured at a rate of 1000 velocity fields per second (2000 camera frames/sec). The measurement region was approximately 100 mm × 50 mm, and covered the central portion of the duct, beginning approximately 50 mm downstream of the fan. The seeding particles used were 1 micron olive oil droplets generated using a TSI Model 9307 laskin nozzle droplet generator. A schematic representation of the field of view in relation to the circular duct can be seen in fig. 2.

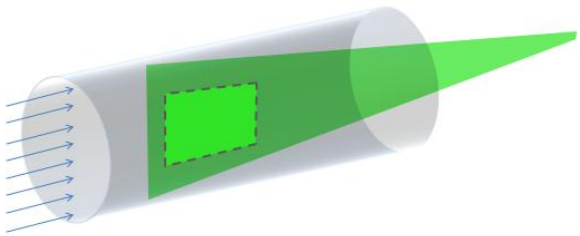

Fig. 2. Schematic of the measurement location in relation to the transparent duct. Flow is from left to right through the duct. The green represents the location of the laser sheet, and the dashed rectangle represents the measurement location.

Using the unique timing setup features of Insight4G™ software and the TSI Model 610035 synchronizer, the time between laser pulses can be set independent of the camera frame rate, to more accurately match the dT with the velocities present in the flow. For this reason, the dT (delta time between laser pulses) in the current experiment was set to 300 microseconds. This setup uniquely allows for the time between subsequent frames to alter between two dT values. In the current setup, this allowed for dT of 300 microseconds between the A and B frames, and a dT of 700 microseconds between the B and A frames. The advantage of this timing setup is that two different characteristic velocities can be optimized for, simultaneously. The images can then be processed to analyze 'slow' and 'fast' regions of the flow, within the same capture sequence. A timing plot from the Insight 4G capture tab can be seen in fig. 3.

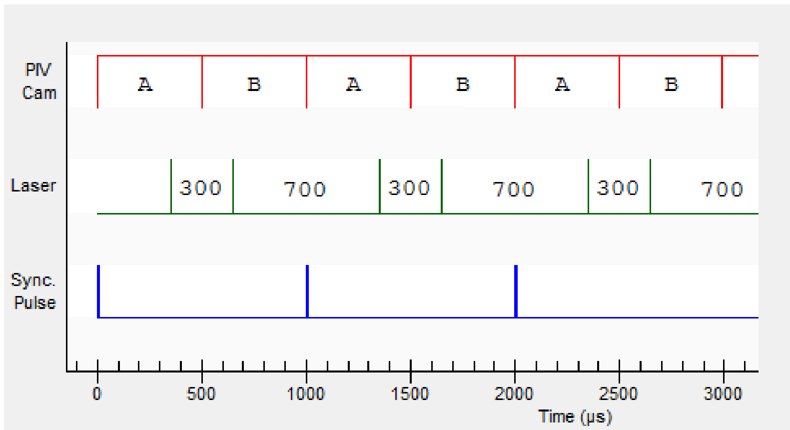

Fig. 3. Timing diagram for the current experiment. The A and B frames are labeled, as well as the alternating dT times (300 and 700 microseconds).

A series of images were captured and image pre-processing was performed in order to optimize the images for correlation processing. The pre-processor from Insight 4G software that was used was the background subtraction pre-processor. In this step, the series of images were scanned, and the minimum intensity recorded for each pixel across the series. This was then set as the background image. This allowed for any stationary intensities in the field of view to be isolated. The background image was then subtracted from the original raw images, revealing only the transient (moving) particles within the flow. Fig. 4 shows an example raw image (left), background image (center), and final image (right). Note the reflections off of the transparent duct (horizontal hazy bands—visible in the left and center images) and the dirt spots (darker dots in the center image), that are eliminated from the images in this step.

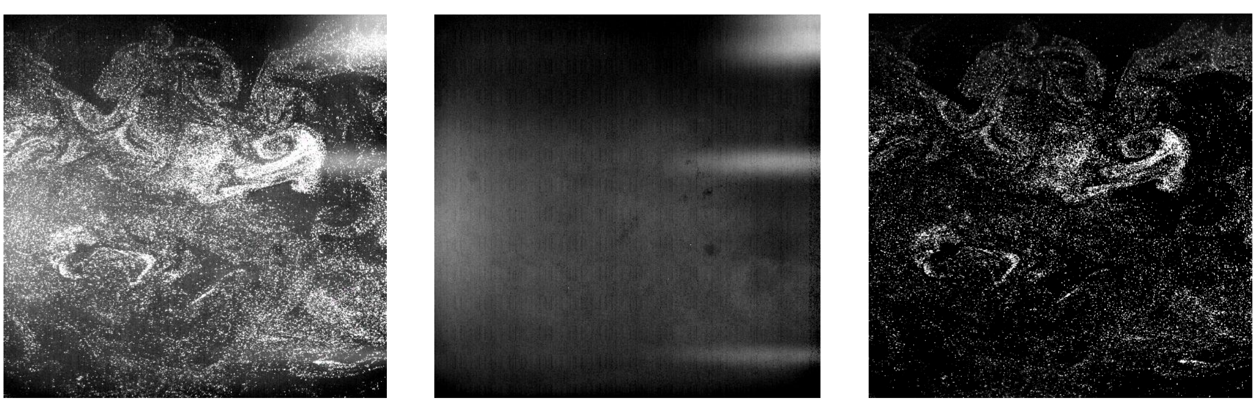

Fig. 4. Benefit of image background subtraction. The images shown are the original image (left), background image (center), and background-subtracted image (right).

The cross correlation was performed on both the A-B and B-A pairs. The A-B pairs were optimized for the faster moving flow near the top and bottom of the field of view, while the B-A pairs are optimized for the slower moving flow near the core. An instantaneous velocity field is shown in fig. 5, with the smaller B-A correlation superimposed on the larger A-B correlation. The color contour is the streamwise (horizontal) velocity. This approach allows for a higher dynamic range of velocity measurements within the PIV system.

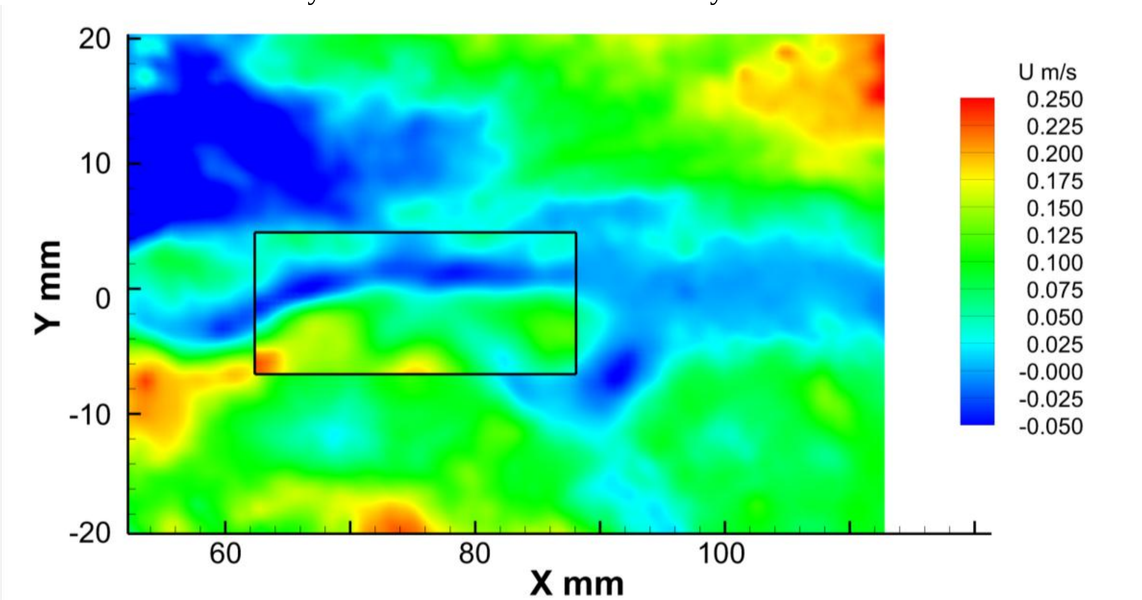

Fig. 5. Instantaneous velocity field showing the streamwise velocity contour. The inset box is the region where a larger delta T value was used, increasing the dynamic range of the measurement.

The time-sequence was also analyzed. Of particular interest was the evolution of the vorticity over time. Using the time-series toolbox, the vorticity at a single point was plotted as a function of time. The results can be seen in fig. 6.

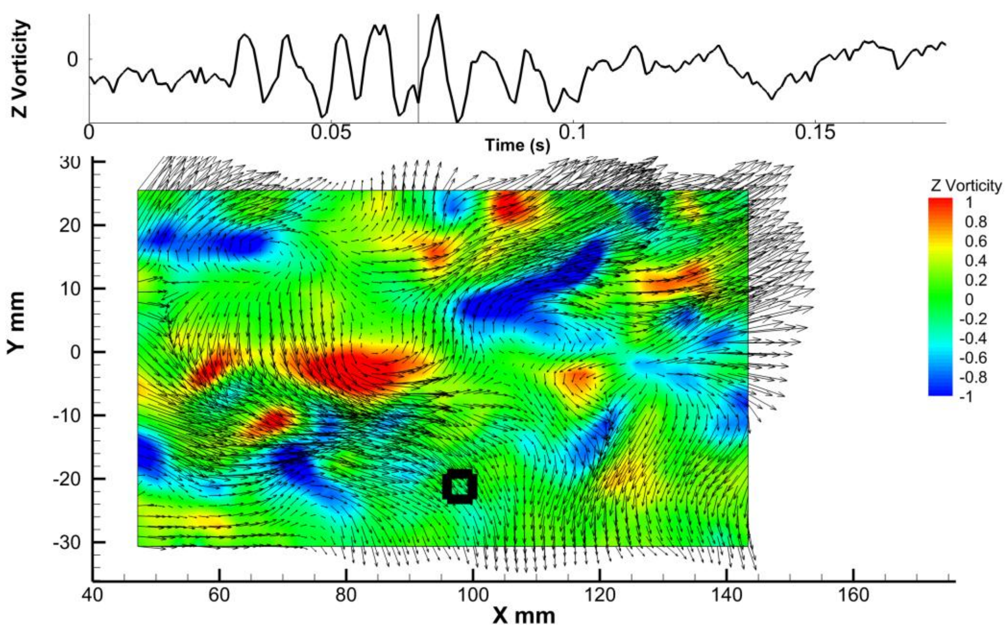

Fig. 6. Instantaneous velocity field with time trace. The contour is vorticity with velocity vectors overlaid. Above the plot is the time trace for the vorticity at a single point within the velocity field (shown in the small black square in the plot).

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