TIME-RESOLVED PIV EXAMINATION OF PROPELLER TIP VORTICES

APPLICATION NOTE TRPIV-002

Propeller Tip Vortices

Tip vortices generated by a stationary model airplane propeller were analyzed using a time-resolved PIV system. Vorticity was examined along a plane just downstream of the prop wash. The data was examined using the TSI® time-resolved PIV toolbox.

Experimental Setup

The propeller had a diameter of 7 inches (177.8 mm) and was powered by a motor operating at approximately 180 rpm. The vertical measurement plane was positioned approximately 5 mm downstream of the blade tip. Olive oil droplets with mean diameter 1 micron, were generated using the TSI Model 9302 Single Jet Atomizer, and were introduced upstream of the blade, which drew the seeding into the measurement region. A dual-head, pulsed Nd:YLF laser operating at 527 nm with maximum energy of 20 mJ/pulse at 1 kHz was used to illuminate the flow. A high speed CMOS camera was operated at 1000 Hz with a pixel resolution of 1280 × 800, and was used to capture the images. The measurement region size was 35 × 55mm. A photograph showing the locations of the fan blade, light sheet, measurement location (dashed line), and camera lens, can be seen in fig. 1 on next page.

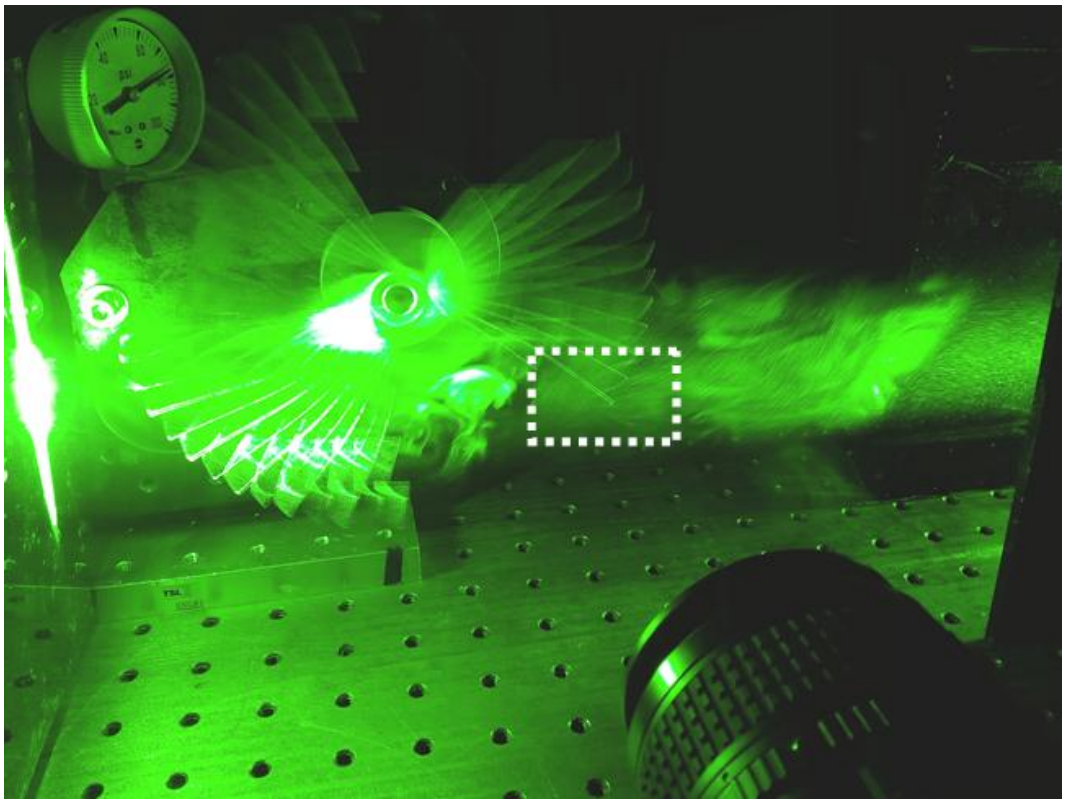

Fig. 1. Photograph showing the locations of the fan blade, light sheet, and camera. The dashed line represents the approximate measurement location.

Images were captured and analyzed using the TSI Insight 4G™ Global Imaging, Analysis, and Display Software. The capture rate was 1000 Hz, and adjacent frames were cross-correlated for the current experiment, for a delta T time between laser pulses of 1000 microseconds.

Figure 2 shows an average velocity field generated from 250 image pairs. The interface between the fast-moving wake and the background flow is seen as the separation between the blue region (lower right) and the yellow/orange region (upper left). The shear layer between these two regions defines the location where the tip vortices most commonly occurred.

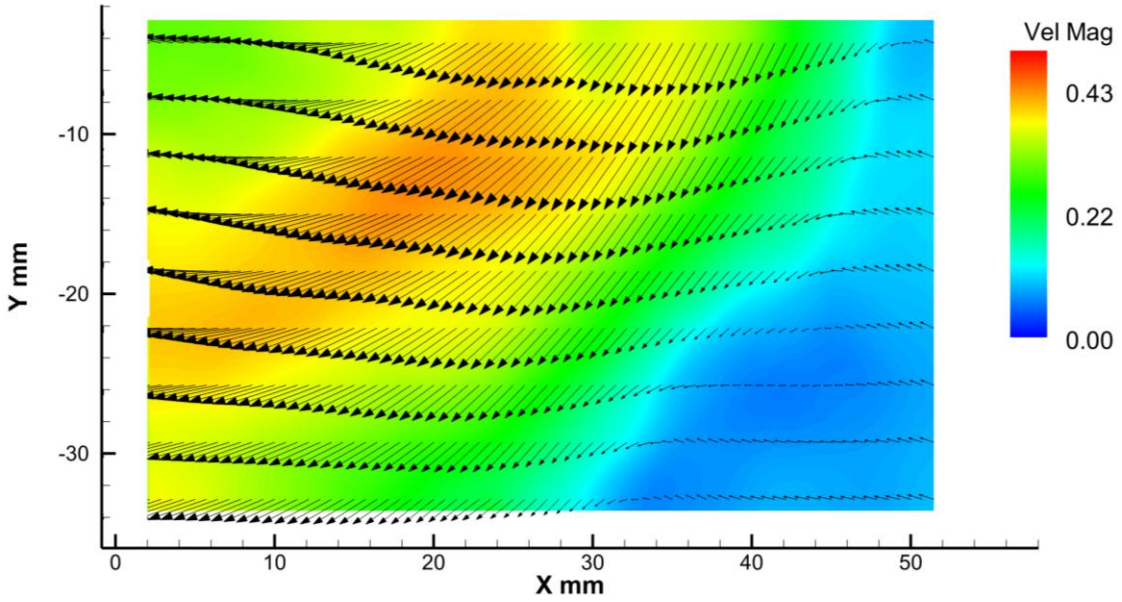

Fig. 2. Average velocity field with contour of velocity magnitude. Vectors are overlaid on the contour, with every 5th vector shown in the vertical direction for clarity.

An instantaneous velocity field can be seen in fig. 3. The mean velocity field has been subtracted in order to accentuate the flow features. The color-contour represents vorticity normal to the plane (blue—clockwise, red—counter-clockwise). Streamlines are also overlaid to show the relative location of vortices at this time instant. Notice the tip vortex prominently seen in the center-right of the plot in red. This is typical of the tip vortices seen, and the trajectory was from the top-right portion of the field of view diagonally downward toward the center-bottom of the field of view.

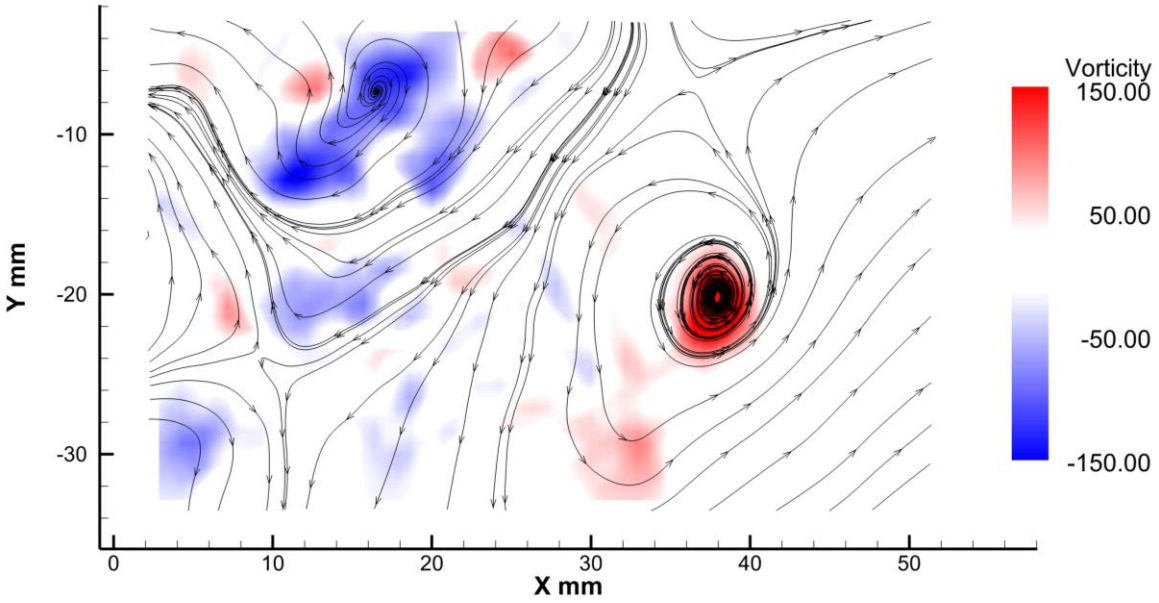

Fig. 3. Instantaneous velocity field with vorticity contour and streamlines. In this field, a tip vortex is clearly seen as the large red (counter-clockwise) rotating vortex near the center-right of the field.

Figure 4 shows the mean velocity field contour with streamlines. In addition, the plot contains white dashed lines superimposed on the field that illustrate the trajectories of several vortex cores traced over time. The trajectories travel from top-right toward the lower-middle part of the plot. Note that the locations of the tip vortex cores correspond to the shear layer seen in the mean (interface between fast and slow moving air).

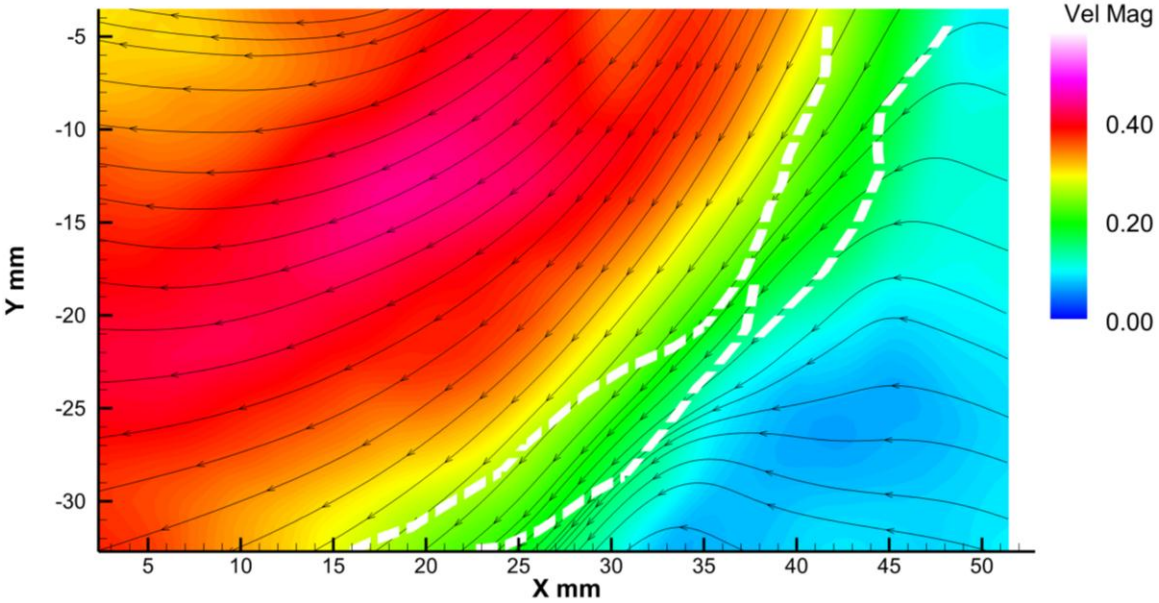

Fig. 4. Mean velocity field with velocity magnitude contour and streamlines. White dashed lines on the plot represent the trajectories of tip vortex cores.

UNDERSTANDING, ACCELERATED

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