VORTEX RING

2008 Award Winner

APPLICATION NOTE V3V-001

Vortex rings are fundamentally important to the area of fluid mechanics due to their prevalence in a variety of flows including turbulent flow fields. A vortex ring is created when an impulse is applied to a finite volume of liquid. The total impulse determines the circulation and propagation speed of the ring (Webster and Longmire, 1998). A photo of a vortex ring formed with dye is shown in Fig. 1.

Figure 1: Vortex ring in water formed with rhodamine dye.

In this experiment, an axisymmetric vortex ring was generated by displacing a volume of fluid through a cylindrical syringe with inner diameter 45 mm. At the edges of the syringe, the flow separated and formed a cylindrical vortex sheet that produced the vortex ring.

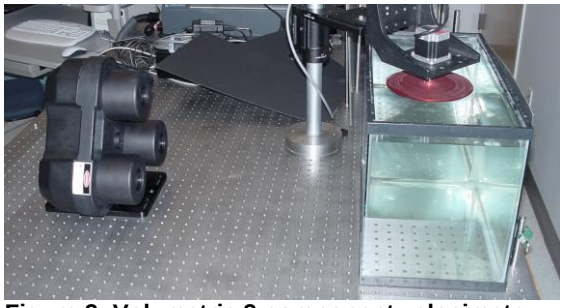

Figure 2: Volumetric 3-component velocimetry (V3V) system.

The TSI V3V™ (Volumetric 3-Component Velocimetry) system was used to analyze the resulting flow structure (Fig. 2). The flow was illuminated by a model YAG120-NWL 120 mJ dual-head pulsed Nd:YAG laser operating at 7.25 Hz and 532 nm wavelength.

Light cone optics were used at the exit of the laser to shape the beam into an illuminating cone. The laser cone was formed with two -50mm cylindrical lenses mounted at 90° to each other. These cylindrical lenses diverged the beam in the horizontal and vertical directions to illuminate a volume approximately 120 mm × 120 mm × 120 mm. The model V3V-8000 3D camera probe consists of three apertures and a total of 12 million pixels. The camera was aligned and calibrated with the CCD a distance of approximately 700 mm from the back plane of the measurement volume.

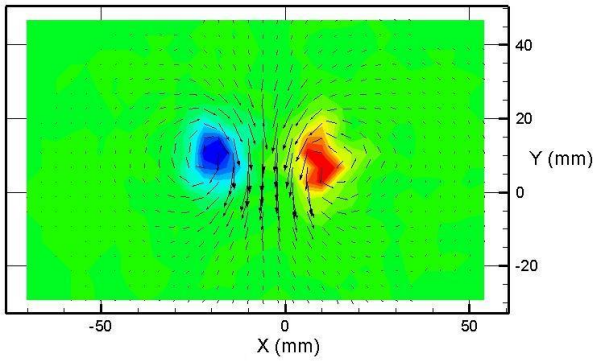

Figure 3: Standard 2D PIV z-vorticity contour plot, overlaid with velocity vectors.

The data capture was synchronized with the model 610035 synchronizer. The images were streamed to the model HYPER2 *HyperStreaming*™ computer, and subsequently analyzed.

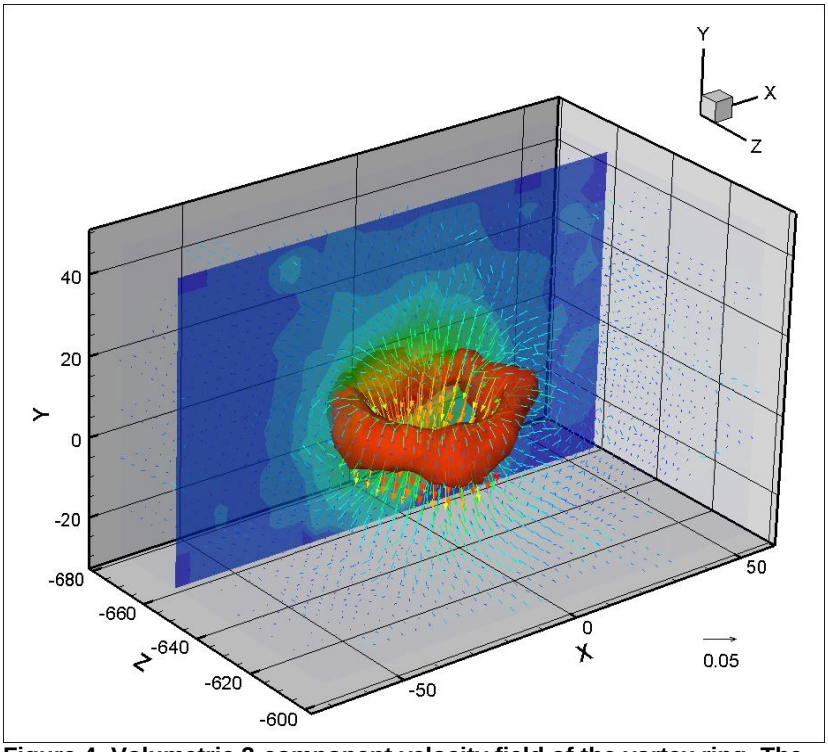

Figure 4: Volumetric 3-component velocity field of the vortex ring. The isosurface represents vorticity magnitude. The slice represents velocity magnitude. The vector size and color represents velocity direction and magnitude.

the negative y-direction. The propagation speed of the vortex ring structure was found to be approximately one-third of the maximum velocity, in this case, 23 mm/s. Figure 5 shows several instantaneous vorticity magnitude realizations overlaid on one plot to show the trajectory of the vortex ring (the ring moves from top to bottom).

In this study, the structure of a vortex ring was examined with the TSI V3V™ system. Instantaneous volumetric velocity fields were obtained, and the results were quantified in terms of the maximum velocity and the propagation speed. The V3V™ data were compared with standard 2D PIV data, and the results matched quite well.

Reference:

D. R. Webster and E. K. Longmire, “Vortex Rings from Cylinders with Inclined Exits,” *Phys. Fluids* **10**, 400 (1998).

The vortex ring was generated in water. The flow was seeded with polycrystalline tracer particles. Two image captures were taken with a Δt of 5 ms, and volumetric velocity fields were obtained through unique particle identification, triplet matching, and particle tracking algorithms in TSI’s *INSIGHT* V3V™ software. Standard 2D PIV was performed on the vortex ring apparatus, as a means to compare the results. A plot of the 2D vorticity field can be seen in Fig. 3.

An instantaneous plot of the V3V™ data can be seen in Fig. 4. A randomly spaced vector field was obtained through particle tracking and then interpolated onto a rectangular grid. Notice in particular the maximum velocity located at the center of the ring. This maximum velocity was 80 mm/s and was directed in

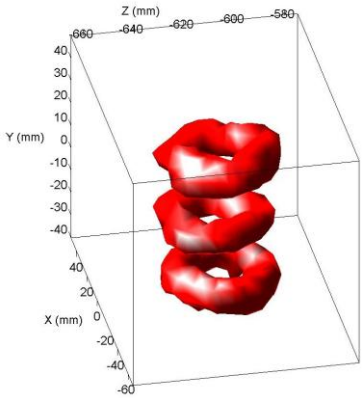

Figure 5: Three instantaneous plots overlaid, showing the vortex ring trajectory.

UNDERSTANDING, ACCELERATED

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