TURBULENT FLOW IN STIRRED TANK REACTORS

2008 Award Winner

APPLICATION NOTE V3V-009

The following application note is based upon the work of Hill *et al*. (2008). For more information and details of the investigation, please consult this paper.

Rushton turbines have been widely studied and used since the 1950s. They are high-shear devices that commonly find application to gas dispersion processes. The flow field in a tank stirred by a Rushton turbine is characterized by a strong radial jet which sets up large ring vortices, one in each half (in the vertical sense) of the tank.

V3V was applied to the Rushton turbine flow for two primary reasons. First, flows in stirred tanks are extremely important to a wide range of engineering disciplines. Second, the flow is extremely complex and highly three-dimensional, making it a suitable test case for the volumetric measurements. Figure 1 shows a photo of the experimental setup.

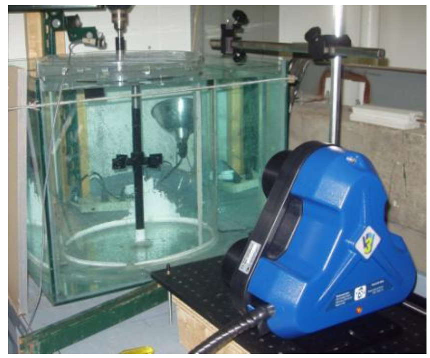

Fig. 1: Photograph of the experimental setup showing the position of the 3D camera relative to the mixer.

The flow field was illuminated from the side with a dual-head Nd:Yag laser emitting light with a wavelength of 532 nm, a pulse width of 12 ns, and energy of 120 mJ/pulse. The two beams were combined to travel on co-linear paths. A light cone was generated with two -25 mm cylindrical lenses mounted at 90° to each other. These cylindrical lenses spread the beam in the horizontal and vertical directions to illuminate a measurement volume approximately 120 mm height × 120 mm width × 100 mm depth (Fig. 2). Beam blocks were placed at the edge of the rectangular water tank in order to clip the laser cone to illuminate only the volume depth being measured and reduce background noise. The flow was seeded with 100 µm polycrystalline particles.

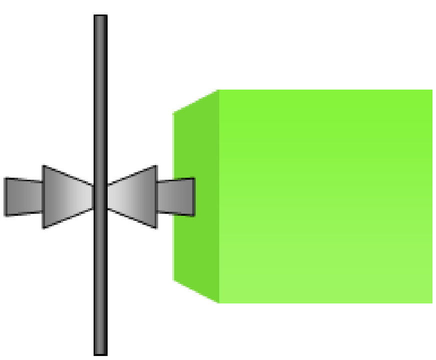

Fig. 2: Schematic of Ruston turbine showing the V3V measurement region

The V3V-8000 camera was aligned and calibrated with the CCD a distance of approximately 800 mm from the back plane of the measurement volume. The data capture was synchronized with the model 610035 synchronizer. The images were streamed to the model HYPER2 HyperStreaming® computer, and subsequently analyzed. For each individual capture, approximately 15,000 independent vectors were achieved.

The average of 250 phase-locked instantaneous captures of the V3V data for the 295 RPM (Re = 107,000) case can be seen in Fig. 3. In the plots, the slices and the red and blue isosurfaces represent normalized angular vorticity. The direction of rotation is clockwise when viewed from above. Notice in particular the presence the positive and negative tip vortices extending from the blade tips.

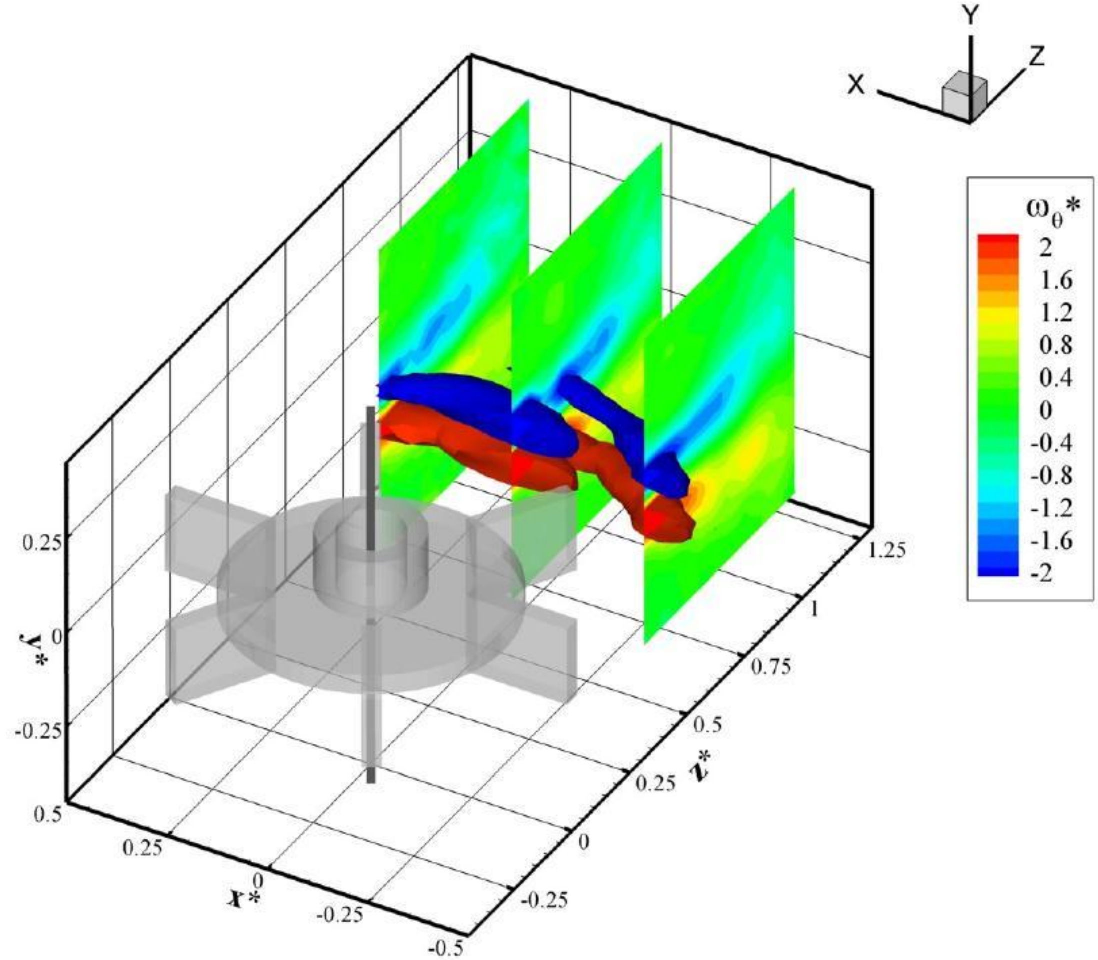

Fig. 3: Volumetric 3-component velocity field of the Rushton turbine, comprised of 250 phase-averaged captures. Isosurfaces and vertical slices of mean, normalized angular vorticity (w_θ*) for the 295 rpm case. *

Reference

Hill, Troolin, Walters, Lai, and Sharp (2008) Volumetric 3-component velocimetry (V3V) measurements of the turbulent flow in stirred tank reactors, *14th Int Symp on Applications of Laser Techniques to Fluid Mechanics.*Lisbon, Portugal, 07-10 July, 2008.

** Fig. 3 reproduced from Hill et al. (2008) and not subject to copyright.*

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