VOLUMETRIC MEASUREMENTS OF A TURBULENT BOUNDARY LAYER

APPLICATION NOTE V3V-FLEX-001 (US)

The Turbulent Boundary Layer

Turbulent boundary layer (TBL) flows are ubiquitous within fluid mechanics. A common feature in wall-bounded TBLs are the presence of hairpin packets—a grouping of individual hairpin-shaped vortices aligned in the stream-wise flow direction and moving at roughly the same speed. This application note describes a volumetric study of these structures. For more information on this study, please refer to the work of Tan et al. (2016).

Experimental Setup

Measurements were conducted at the University of Minnesota—Department of Aerospace Engineering—Turbulent Shear Flows Laboratory water channel with a freestream velocity of 0.508 m/s, a water depth of 390mm, and seeded with 13 micron silver-coated hollow glass spheres. At the measurement location, the boundary layer thickness, δ was 125.5 mm, and Re_τ was 2500. For more details on the water channel refer to Zheng and Longmire (2014). Four 8MP cameras fitted with Scheimpflug mounts were mounted above the water channel aimed downward to view the boundary layer through a viewing box placed on the water surface. The measurement region was illuminated with two dual-head Nd:YAG lasers operating at 5 Hz, with nominally 380 mJ and 200 mJ per pulse, respectively. A photo of the experimental setup can be seen in fig. 1.

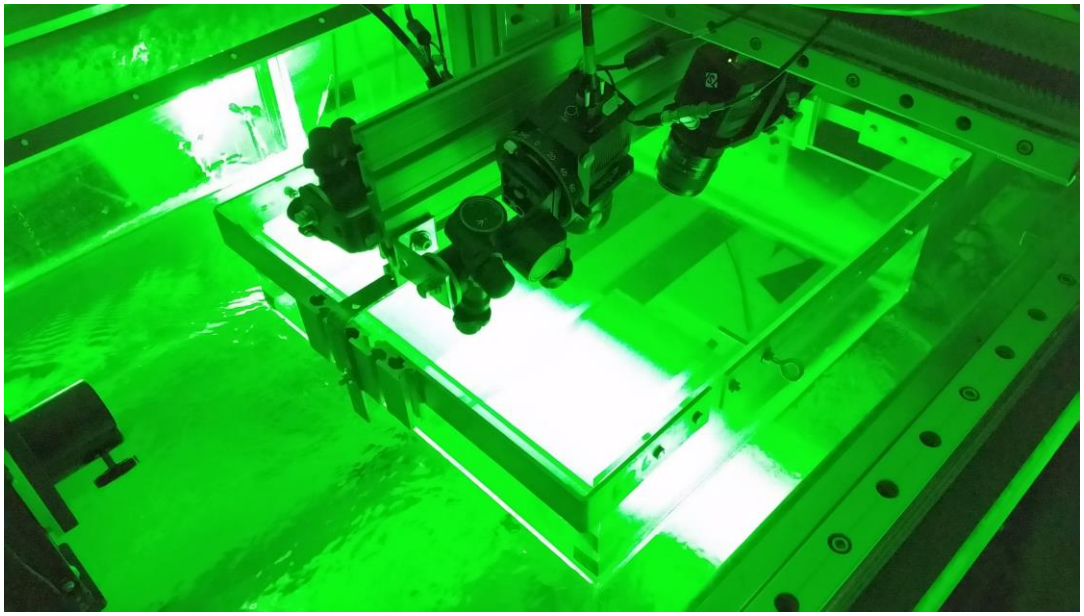

Fig. 1. Experimental setup showing the cameras viewing the boundary layer flow through the glass box placed at the surface, and the laser illuminating the measurement region.

Results

The resulting measurement volume was 90 × 85 × 20 mm. An instantaneous velocity field is shown in fig. 1. The green isosurface of 0.33 m/s ($0.65U_\infty$) for streamwise velocity highlights regions of low momentum that are coherent along the streamwise direction, and typically coincident with packet structures. Red and blue isosurfaces show regions of relatively high swirling strength based on the Q criterion (colored based on the sign of the wall-normal vorticity). In this instance, many swirling structures were present, some resembling hairpins flanking the low momentum regions, for example, the structure present near x, y = (-0.2, -0.1).

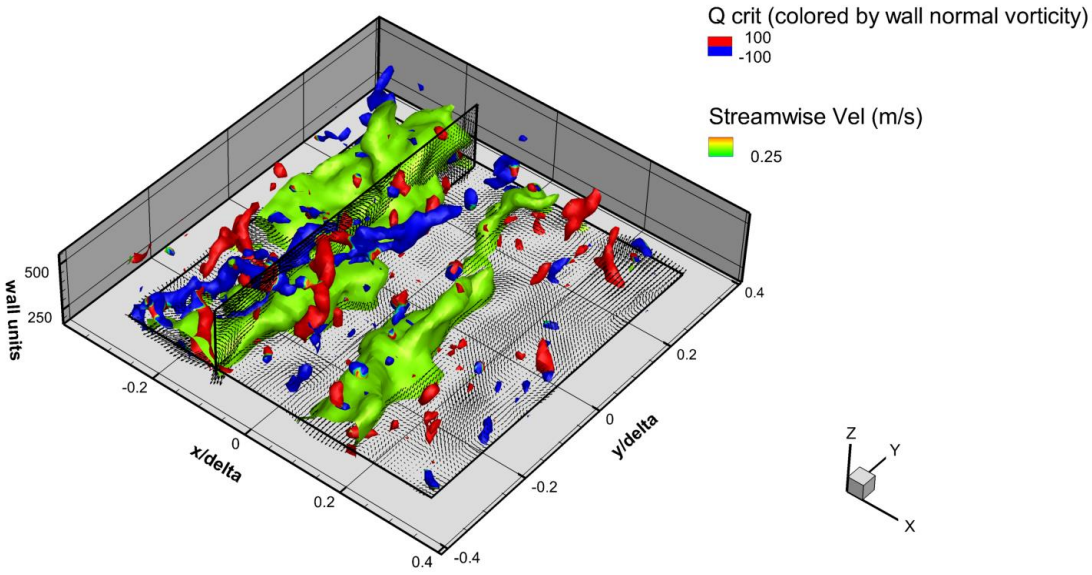

Fig. 2. Velocity data from the V3V-Flex system. Green isosurfaces denote streamwise velocity of 0.33 m/s ($0.65U_\infty$). Red/blue surfaces show Q criterion thresholded at 100 s^{-2}, colored by wall-normal vorticity to show positive and negative swirling directions. Galilean decomposition has been applied to the vectors shown within the slices where an approximate convection velocity of 0.36 m/s ($0.71U_\infty$) were subtracted to illustrate the fluctuation in streamwise velocity.

References

Tan YM, Troolin DR, Lai WT, Longmire EK (2016) "Volumetric measurements of vortex packet recovery downstream of a perturbation," *18th International Symposium on Application of Laser Techniques to Fluid Mechanics*, Lisbon, Portugal, July 4–7, 2016.

Zheng S and Longmire EK (2014) "Perturbing vortex packets in a turbulent boundary layer," *J. Fluid Mech*, **748**, 368-398.