LARGE-SCALE V3V™ MEASUREMENTS IN A WINDTUNNEL

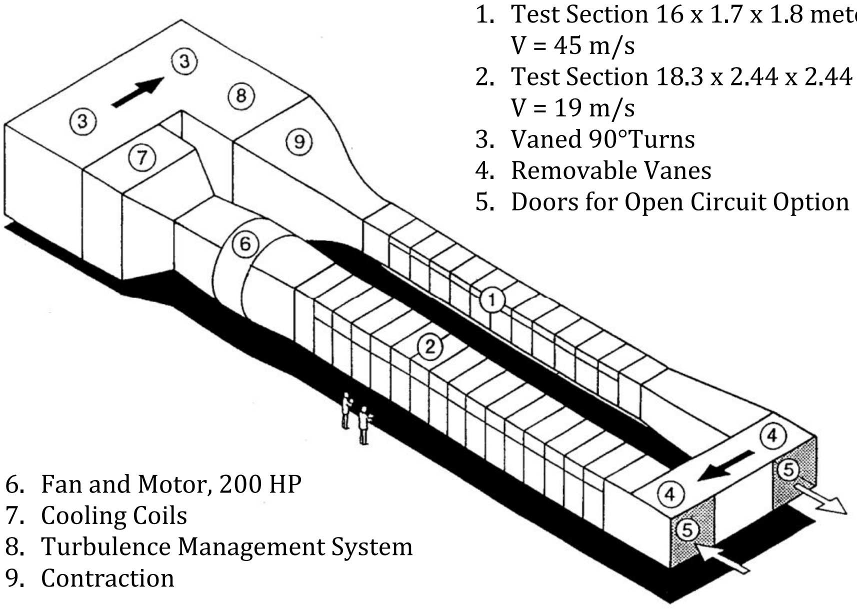
APPLICATION NOTE V3V-FLEX-014 (A4)

Introduction

Large-scale volumetric velocity measurements were made in a wind tunnel using a V3V-Flex™ system from TSI® Incorporated. A bubble generator was used to create micro-bubbles suitable as tracers for seeding the flow. The flow downstream of a cylinder was measured.

Experimental Setup

The experiments were run in the closed-return Atmospheric Boundary Layer Wind Tunnel at the Saint Anthony Falls Laboratory - University of Minnesota (fig. 1). The wind tunnel has a plan length of 37.5 m and a test section (section 1) of 16 (l) × 1.5 (w) × 1.7m (h). The contraction region upstream of the test section consists of a 6.6:1 area ratio with flow condition coarse wire mesh and honeycomb flow straighteners. A 200 h.p. fan drives the wind tunnel. The turbulence intensity at the center of the tunnel in a freestream condition is approximately 1% (Chamorro and Porte-Agel, 2009).



1. Test Section 16 x 1.7 x 1.8 meters, V = 45 m/s
2. Test Section 18.3 x 2.44 x 2.44 meters, V = 19 m/s
3. Vaned 90°Turns
4. Removable Vanes
5. Doors for Open Circuit Option
6. Fan and Motor, 200 HP
7. Cooling Coils
8. Turbulence Management System
9. Contraction

Figure 1. The Saint Anthony Falls Atmospheric Boundary Layer Wind Tunnel.

Schematic: eolos.umn.edu

A V3V-Flex™ system with four 8MP cameras operating at 3 Hz and fitted with 60-mm lenses with aperture setting of f#11, nominal magnification of 0.05, and Scheimpflug mounts were aligned in a forward scatter line arrangement. The wind tunnel was seeded with micro-bubbles of mean diameter 15 μm generated by a model# BG-1000 micro-bubble generator (Fig. 2). Details concerning the bubble generation can be found in Barros et al. (2019). The scattered laser light from the bubbles formed images on the camera sensors with average diameters of approximately 2.5 pixels. The bubbles stayed suspended for long periods of time and after 30 minutes with the bubble generator turned off, approximately 25% of the bubbles remained.

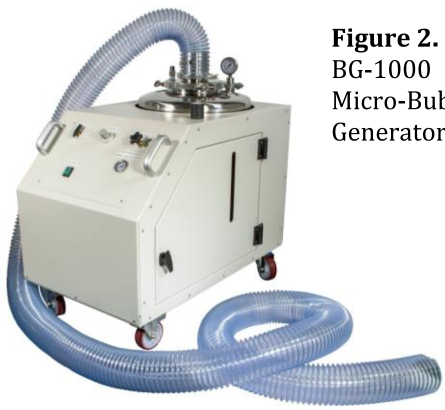


Figure 2. The BG-1000 Micro-Bubble Generator.

A cylinder of diameter 50.8-mm was positioned with its axis along the spanwise direction near the center of the wind tunnel cross-section. The cylinder was located approximately 5 diameters upstream of the measurement volume. The freestream velocity was nominally set to 5 m/s.

The measurement volume was illuminated by a 200 mJ/pulse dual-head Nd:YAG laser positioned on top of the wind tunnel with a mirror directing the illumination down into the test section through a window on the top of the tunnel. Laser volume forming optics were used to generate the illumination volume. A photo of the experimental setup can be seen in fig. 3. A model# 610036 synchronizer timing device coordinated the laser pulses and camera image capture, and the data was processed with INSIGHT V3V-DPIR™. Details of the processing routines used can be found in Boomsma and Troolin (2018).

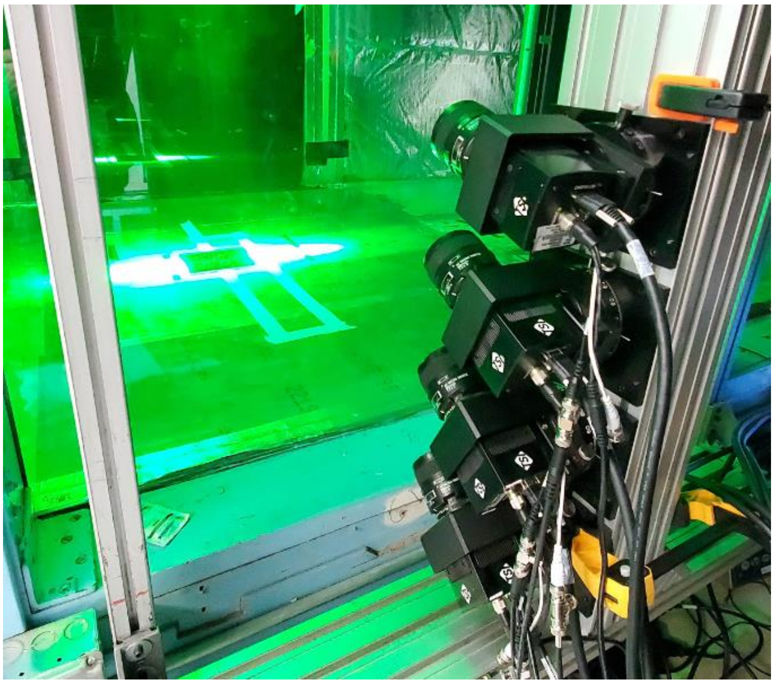


Figure 3. The experimental setup showing the layout of the cameras, laser, and experimental test section.

Results

An instantaneous vector plot of the streamwise velocity field can be seen in fig. 4. The measurement volume was 300 × 250 × 54 mm. The convection velocity has been subtracted from the vectors in order to clarify the vortices located in the wake. The turbulent wake downstream of the cylinder is clearly visible. Regions of blue indicate lower streamwise velocity corresponding to the wake region and vortices shed from the horizontally-oriented cylinder.

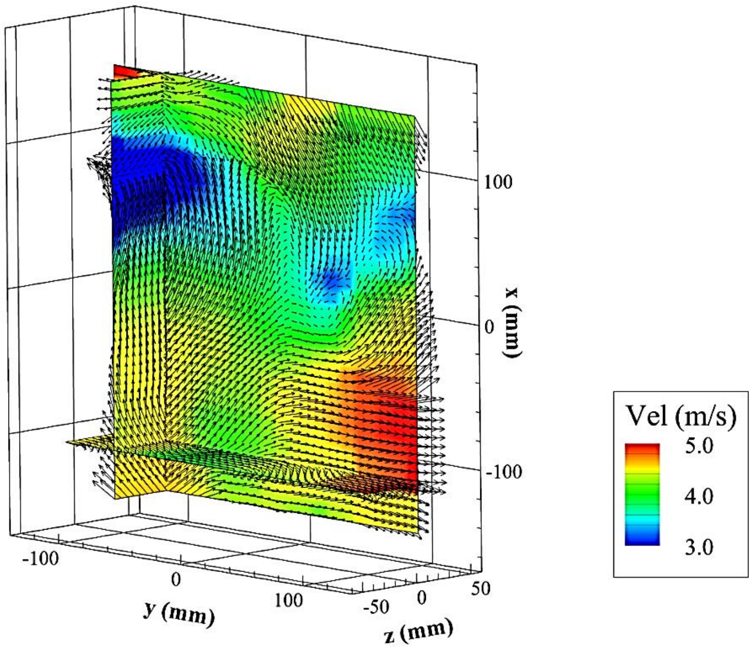


Figure 4. Instantaneous streamwise velocity measured in a volume 30 × 25 × 5.4 cm^3.

Conclusion

A V3V-Flex™ system with a micro-bubble generator were used in order to measure large-scale volumetric velocity measurements within a closed-return wind-tunnel. The particle images generated by the bubbles were well-suited for volumetric particle tracking within a volume of 30 × 25 × 5.4 cm^3.

References

Barros D, Duan Y, Troolin D, Longmire EK, Lai W (2019) Soap bubbles for volumetric velocity measurements in air flows, *19th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics*, Munich, Germany, July 22-24, 2019.

Boomsma, Troolin (2018) Time-Resolved Particle Image Identification and Reconstruction For Volumetric 4D-PTV, *19th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics*, Munich, Germany, July 22-24, 2019.

Chamorro LP, Porte-Agel F (2009) a Wind-Tunnel Investigation of Wind-Turbine Wakes: boundary-Layer Turbulence Effects, *Boundary-Layer Meteorol*, **132**:129-149. DOI 10.1007/s10546-009-9380-8.

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