LARGE-SCALE DUAL PIV MEASUREMENTS IN A WIND TUNNEL USING SOAP BUBBLE TRACERS

APPLICATION NOTE PIV-029 (US)

Introduction

Large-scale, multi-camera, particle image velocimetry (PIV) measurements were made in a wind tunnel using air-filled soap micro-bubbles as the seeding tracer particles. The flow downstream of a horizontal axis wind turbine model was measured. Two synchronized high-speed cameras imaging adjacent fields of view captured velocity fields that were subsequently stitched together creating a large-scale velocity field with high spatial resolution.

Experimental Setup

The experiments were run in the closed-return Boundary Layer and Subsonic Wind Tunnel at the Erik Jonsson School of Engineering and Computer Science, Department of Mechanical Engineering at the University of Texas - Dallas (fig. 1). The wind tunnel has a total circuit length of ~140m and a test section of 30 (l) × 2.8 (w) × 2.1m (h). The contraction region upstream of the test section consists of a 5:1 area ratio with flow conditioning and honeycomb flow straighteners. A 255 kW single stage axial flow fan drives the wind tunnel.

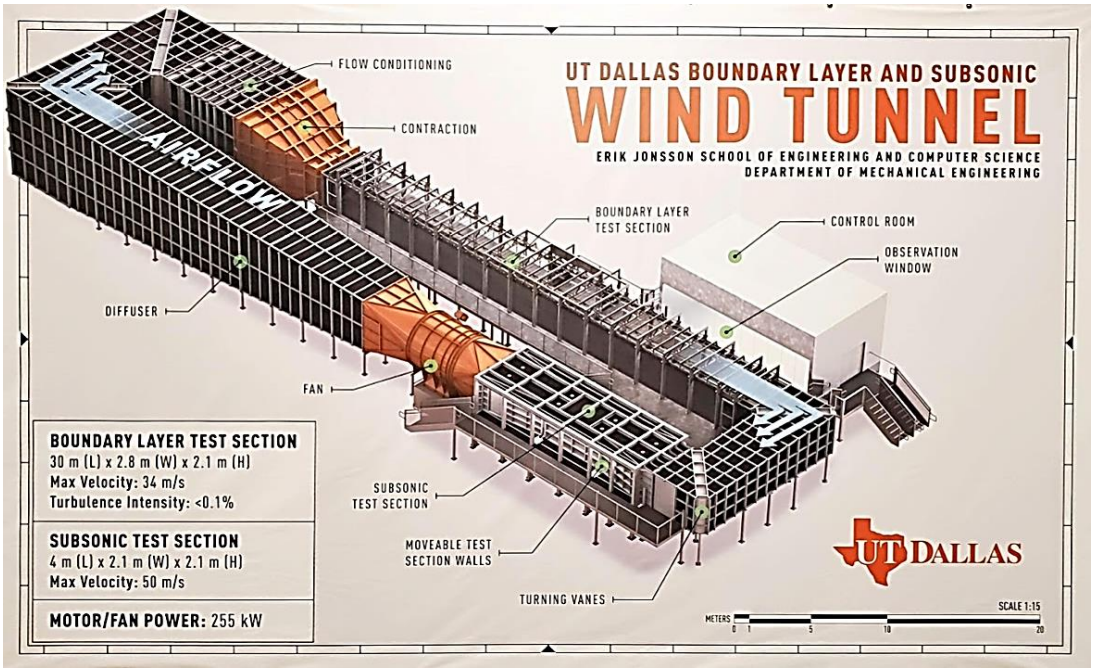

Figure 1. The University of Texas – Dallas Boundary Layer and Subsonic Wind Tunnel *Schematic:* https://www.utdallas.edu/windflux/facilities/

The tests were conducted at a freestream velocity of 7 m/s. The turbulence intensity at the center of the tunnel in a freestream condition is < 0.1%. The boundary layer on the wind tunnel floor was tripped with a long series of surface mounted cubes as can be seen in fig. 3.

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 tracer bubbles were introduced downstream of the test section and traveled the entire length of closed-loop wind tunnel (~140m) before entering the measurement region.

Figure 2. The BG-1000 Micro Bubble Generator.

A 30 mJ/pulse Nd:YLF laser was positioned outside of the wind tunnel so that the beam entered the tunnel downstream of the measurement region at 90° to the freestream direction. A 90° mirror and a set of light sheet forming optics were positioned inside the wind tunnel downstream of the measurement location such that the light sheet propagated from downstream illuminating a plane coincident with the centerline of the model wind turbine.

Two 4 mega-pixel high-speed cameras were positioned side-by-side outside of the wind tunnel test section in order to image adjacent regions downstream of the model wind turbine. The cameras were outfitted with 135 mm lenses. The resulting vector fields were stitched together and the left-most portion of the vector fields exists at two turbine blade diameters (2D) downstream of the model. The field of view for each camera was approximately 230 mm × 325 mm. The cameras were positioned so that the aspect ratio had the longer dimension in the vertical, and the fields of view overlapped by approximately 10 mm, so that the total field of view of the combined measurement region was approximately 440 mm × 315 mm. The scattered laser light from the tracer bubbles formed images on the camera sensors with average diameters of approximately 2.5 pixels.

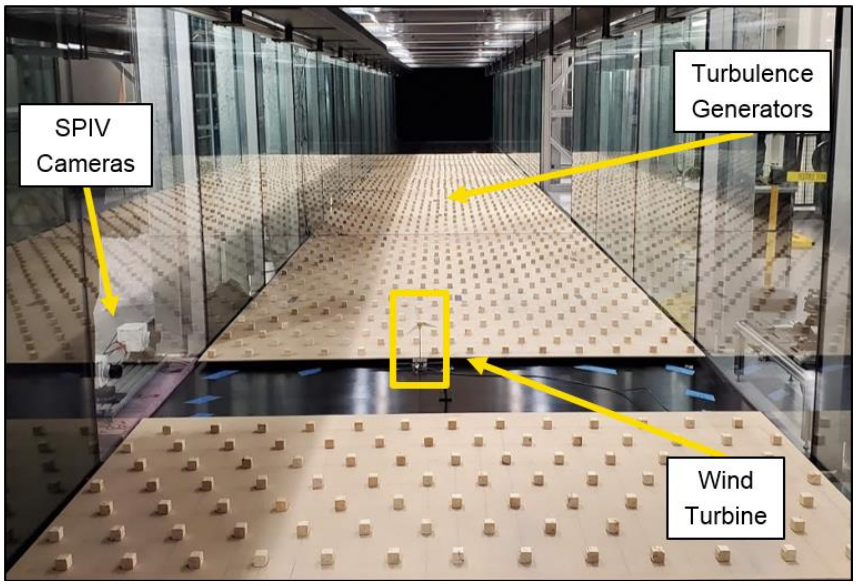

Figure 3. The experimental setup showing the layout of the cameras, turbine model, and experimental test section.

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 4G™ software.

Results

An instantaneous vector plot of the streamwise velocity field can be seen in fig. 4. The measurement volume was approximately 440 × 315 mm. The turbulent wake downstream of the turbine is clearly visible. Regions of blue indicate lower streamwise velocity corresponding to the wake region and vortices shed from the turbine blades.

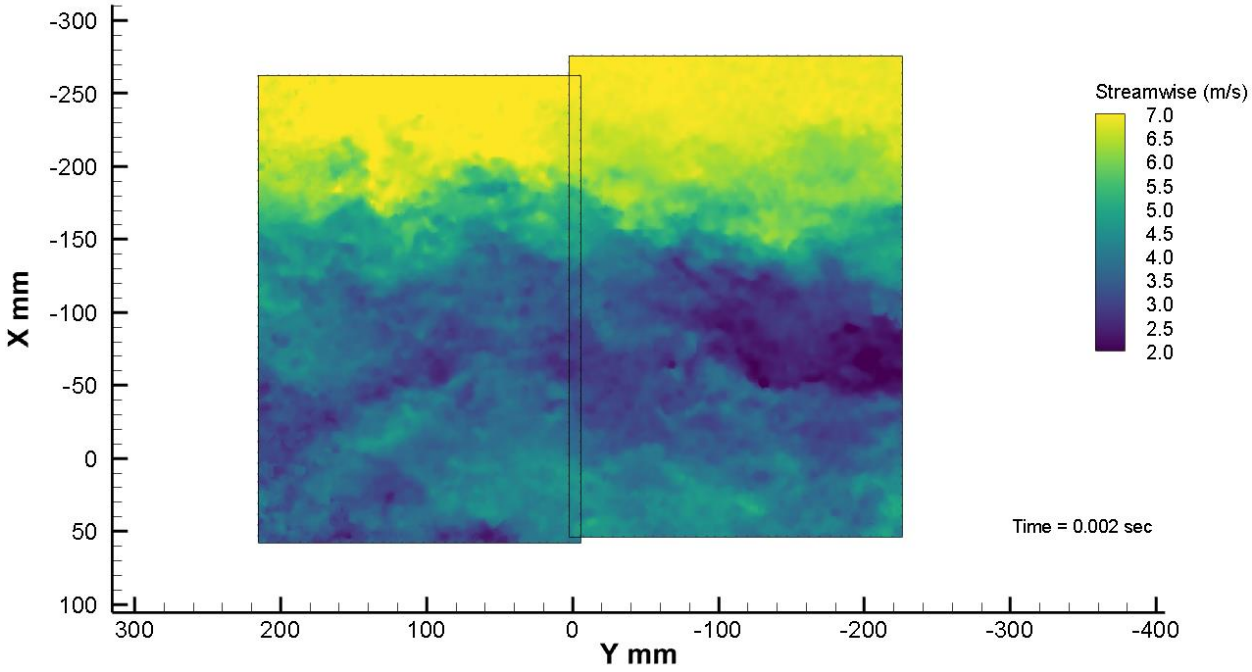

Figure 4. Instantaneous **streamwise velocity field.**

Conclusion

A dual-camera TSI PIV™ system with a micro-bubble seeding generator were used in order to measure large-scale velocity measurements within a closed-return wind-tunnel downstream of a model wind turbine.

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.

Facility and Data Courtesy of:
Prof. Yaqing Jin, Department of Mechanical Engineering, The University of Texas at Dallas,
https://labs.utdallas.edu/ftr/

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TSI Incorporated – Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 680 1220	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

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