Scaling Sensitivity of Focused Laser Differential Interferometry Across Facilities

Paul Medina

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Committee:

Owen J. H. Williams

Pino M. Martin

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Abstract

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Paul Medina

Chair of the Supervisory Committee:
Owen J. H. Williams
Aeronautics & Astronautics

Focused Laser Differential Interferometry (FLDI) is a novel technique that leverages optical interference to measure density fluctuations within high-speed fluids. This technique provides excellent spatial and temporal resolution compared to traditional measurement techniques by offering a non-intrusive diagnostic with fast sample rates (> 1 MHz). Its sensitivity; however, is limited to a narrow range of frequencies and length scales, which depend on the optical elements used and their relative distances. This thesis investigates how the signal response of FLDI changes with the size of a wind tunnel facility. The goal is to alter the optical elements to achieve the same sensitivity across facilities so that data can be directly compared and the underlying physics evaluated. Analytical FLDI transfer functions, derived from Andrew Ceruzzi's Dissertation, *Development of Two-Point Focused Laser Differential Interferometry for Applications in High-Speed Wind Tunnels*, are used to model the theoretical signal response of FLDI. This modeling provides insight into how component variations affect scaling for wind tunnels of three sizes, representative of small

labs to national facilities. In this study, optical components are selected after optimization with the theoretical FLDI transfer functions for the three facility scales, ranging from test section diameters of 1 ft to 4 ft. Theoretical optimization shows that scaling optical components can match the FLDI signal response between facilities. However, larger facilities necessitate greater splitting angles between the orthogonal beams, which decreases the instrument's spatial resolution. Tests at the University of Washington with a canonical jet, simulating the scaling of facility size through optic variation, show large changes in the sensitive frequency region of the instrument. This work highlights the challenge of comparing FLDI data between different wind tunnel facilities, particularly emphasizing the importance of considering the transfer functions and sensitivities of the setups used in each experiment.