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Identification and minimization of errors in Doppler global velocimetry measurements

by

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ABSTRACT

The initial development phase of Doppler Global Velocimetry (DGV) has demonstrated the promise of the technology, the next phase is the identification of measurement error sources and the subsequent reduction of their contributions to measurement uncertainty. The paper describes a laboratory investigation that systematically studied each element of the DGV system. The goal was to identify system characteristics that might prove to be weaknesses in the implementation of the technology. The study began by considering areas that proved to be troublesome during the several wind tunnel entries conducted during the past few years. Many of these areas are related to the lack of robustness of the DGV components to the dynamic environmental conditions encountered during wind tunnel testing.

The transducer mechanism in DGV is based on the ability of Iodine vapor to totally absorb green light at various optical frequencies with narrow absorption bandwidths. Tuning an Argon ion laser or an injection-seeded, frequency-doubled Nd:YAG laser to the midpoint along the side of an absorption line would provide a mechanism to directly measure the Doppler shift of scattered laser light from particles passing through a light sheet. The original cell contained Iodine in both solid and vapor states. Since the absorption process is dependent on the number of Iodine molecules present in the optical path, the temperature of the Iodine must be held constant. Otherwise, the line shape and thus the absorption characteristics will change, causing measurement errors. A vapor-limited Iodine vapor cell was developed and shown to maintain a constant calibration over a range of temperatures. Further, a new calibration technique was developed to obtain accurate and repeatable line profiles with frequency resolutions of 0.28 MHz.

The other principle source of measurement uncertainty was the Nd:YAG laser. The laser would produce 10 nsec pulses with optical frequencies that would vary as much as 80 MHz from pulse to pulse, even if they were *single frequency*. Further, the optical frequency would vary across the beam cross section within each pulse. Systems were developed to measure the average optical frequency of each pulse, and the average cross sectional frequency distribution. Additional systems were developed to determine if each pulse was single frequency.

Other sources of measurement uncertainty were investigated and solutions found to either eliminate or minimize their effects. The following two figures illustrate example velocity measurements obtained using the techniques described in the paper.

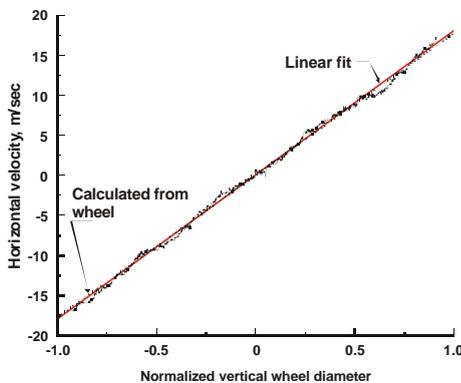


Fig. 17. Horizontal velocity profile along the vertical diameter of the rotating wheel.

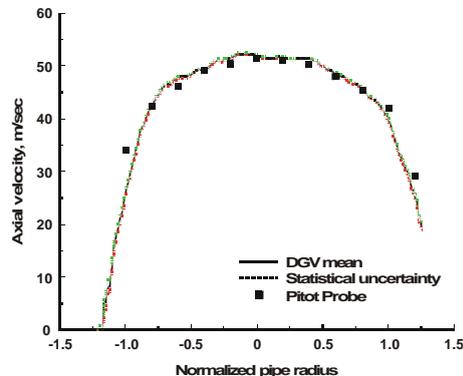


Fig. 18. Comparison of DGV velocity measurements of the jet flow exiting a fully developed turbulent pipe with Pitot probe measurements