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THE RESOLUTION ANALYSIS OF TUNABLE DIODE LASER ABSORPTION SPECTROSCOPY SYSTEM FOR VELOCITY MEASUREMENT OF THE SCRAMJET COMBUSTION FLOW

Abstract

Tunable Diode Laser Absorption Spectroscopy (TDLAS) has been an effective technology to measure the velocity of the combustion flow in hypersonic engine. And the measurement theory is based the relative Doppler shifts of the absorption transition for the upstream and downstream beams in the flow. In this paper, the resolution of the TDLAS system for velocity measurement, which is defined as the minimum velocity change value that the TDLAS system can identify, is analyzed in three aspects, the structure of the beam path, the absorption transition from the laser, and the quantization of the digital signal sampling.

The analysis result shows that the resolution of the velocity measurement increases with the increase of the intersection angle between two beams, and is directly proportional to the chosen absorption transition but inversely proportional to the frequency shift resolution. For the TDLAS system with digital signal processing module, the scanned frequency is quantized by signal sampling, which determines the frequency shift resolution via the sampling rate, the frequency scanning rate and scales. The fluctuation of the laser frequency is also discussed in this paper, while the measurement method can effective eliminate its influence.

An experiment was executed on a scramjet test platform with a TDLAS system of 16 channels which were mounted in isolator and combustor separately. The resolution and the relative precision of the measured velocity were discussed in the cases of steady combustion and after combustion. Experiment results showed that the velocity resolution of this TDLAS system was 21 m/s. During the steady combustion period, the measured velocity fluctuated around the mean value of 1113 m/s. The uncertainty of the velocity was statistically less than 2 velocity resolutions of 42 m/s at the conference level of 90.56%, which generated a 3.65% measured precision. After combustion, the flow's velocity decreased gradually, but the amplitude of the fluctuation kept at the same level as before, then the precision increased and reached to 5% at the measured velocity of 840 m/s. The research in this paper is valuable to guide the design of TDLAS velocity measurement system based on the structure of the scramjet.