Chapter 5
Future Work and Recommendations

This section presents several recommendations for improvement of each of the measurement techniques developed in this study. If the current study is continued, these recommendations can provide more robust measurements, higher quality results, and can simplify experiment implementation and operation. The Mie scattering flow visualization can benefit from: the incorporation of 3-D image processing, the application of increased laser power, and the consolidation of data acquisition and experiment control devices. The schlieren flow visualization can be improved through an increase in the collimated beam light intensity, maximization of the density ratio between the air and 'fuel' gas, and an upgrade of the camera mounting hardware. Possible improvements to the LDV include addition of the abilities to measure velocity direction as well as magnitude and to measure the fluctuating velocity components.

5.1 Mie Scattering Flow Visualization Recommendations

The 2-D images captured during the Mie scattering experiment provide great insight into the nozzle outlet flow, as discussed in this thesis. However, additional insight could be gained from a 3-D perspective of the flow. Incorporation of software such as Tecplot will allow the 2-D images captured from across the flow to be combined into a single 3-D image, permitting a more rigorous investigation into the nozzle flow field and additional modes of comparison with the CFD results.

Secondly, argon gas has slowly been diffusing out of the laser plasma tube (that was used in the present study) over the past three years, which causes a reduction in output power for the same electrical power input. Until recently, as a temporary remedial measure, the aperture was opened and then the input power was increased to continue to maintain a constant laser power. During spring semester of 2006, the laser power continued to drop to 0.5 Watts, and there is little headroom left for the input power to be increased further. Therefore, the plasma tube will need to be refilled soon, which will raise the laser power to at least 1.5 Watts, greatly increasing the intensity of the laser sheet. With more intense illumination, the camera and intensifier gains can be turned down, which leads to less grainy and better focused images from the Mie scattering experiment.

Finally, in its current state, the Mie scattering flow visualization system requires the use of two computers for its operation. The image computer contains the video capture card, LabVIEW code required to sample images from the camera, and also contains the serial camera control uplink accessed through Hyper Terminal. The other required functions include air flow rate measurement and translation stage control, which are performed through a DAQ board and LabVIEW code in the LDV computer. The purchase of an additional DAQ board for the image computer would allow it to house all functions required for the Mie scattering experiment. This modification would simplify the operation of the experiment. Further, if the smoke generator oil bath temperature, smoke generator supply voltage, and electronic air supply pressure regulator were controlled and measured in LabVIEW through the new DAQ board, fully automated experiments could be run across a range of conditions.

5.2 Schlieren Flow Visualization Potential Improvements

Initially, the brightness, and therefore clarity, of the schlieren images could be enhanced through two possible methods. A higher power arc lamp bulb could be installed in the light source to directly provide additional power, or a new light source focusing lens could be found that would focus more of the light from the source into the pinhole. Currently, the light source beam can only be focused to 300% the size of the pinhole, meaning only one third of the source light travels through the pinhole to the remainder of the optical system. The other two thirds is blocked by the pin hole plate.

Secondly, increasing the density difference between the two gases mixing in the nozzle will create more distinct density gradients and consequently, sharper schlieren images. The air flow could be replaced with a heavier gas to increase the density difference or the air could be cooled to increase its density. Helium, being inert, could also be safely heated to increase the density difference. Just by, heating the helium from room temperature to 300°F increases the density ratio with air from 7.23 to 10.38.

This final recommendation with regards to the schlieren system applies to the camera mounting. Currently, installation and optimization of the schlieren camera is a challenging and time-consuming process. The camera mounting bracket only permits coarse adjustment of the camera location and angle, making the required precision alignment of the camera difficult. The acquisition and installation of a two-axis translation stage with two tilt-axes for camera mounting would permit rapid and simple optimization of the camera position during preparation for a schlieren measurement. The camera must be able to translate in a plane perpendicular to the axis of the light beam.

5.3 LDV Upgrade Potential

First, the LDV is currently restricted to measurement of the mean velocity magnitude for two components; however, it can be modified to measure both velocity magnitude and direction through frequency shifting. The existing LDV produces a standing interference pattern in the probe volume, so a particle passing through in either direction returns the same Doppler shift. If one of the beams in each pair is frequency shifted, using an optoelectric device called a Bragg cell, a moving interference pattern is generated in the probe volume. In this case, a particle moving through the probe volume in the positive direction will return a Doppler frequency greater than the shift frequency, and a particle moving in the negative direction will return a Doppler frequency less than the shift frequency. This technique can be used to determine velocity direction. Magnitude is then determined by electronically mixing the returned Doppler frequency with the shift frequency to find the standing interference pattern Doppler frequency, currently used for velocity magnitude computation. Typically, a shift frequency around 40 MHz is applied, which does not affect the color of the light because it is only a small fraction of the Terahertz light wave. The Bragg cells, Bragg cell drivers, RF signal generator and electrical mixers required for implementation of direction determination are already present in the RFL. Greater detail regarding the implementation of these devices is explained in the dissertation of Ludwig Haber [5].

Secondly, a two channel high speed DAQ board is currently implemented with the LDV system and each velocity component requires acquisition of two signals, so multiplexing of the two signals from each velocity component is required. This arrangement prevents coincident triggering and sampling of both velocity components, and consequently prevents measurement of the fluctuating velocity component. The capability to measure unsteady velocity components could be added to the LDV through acquisition and implementation of a four channel high speed DAQ board and the corresponding software.

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