CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Flow Visualization

The first goal of this study, to implement a non-intrusive system for the study of mixing was successfully completed. Two systems were developed for this purpose, one utilizing Planar Mie Scattering from smoke particles and the other using Planar Laser-Induced Fluorescence of acetone molecules. Both techniques provided qualitative information on the concentration field of an actively controlled triangular jet that revealed similar flowfield development to the velocity field data available on the same nozzle. Thus, both techniques are valid for basic flow visualization and for collecting data on the concentration field. However, it was evident that the PLIF method was the superior technique for showing the detail of the flow structure.

One important observation in the swirling jet study was the effect of the response times of the camera (which controlled the image acquisition time for the PMS experiments) and excimer laser (which controlled the image acquisition time for the PLIF experiments) on the sampling of the flow when using a square wave, on/off type of excitation. Because of the differences in response times of the camera and the excimer laser, sending identical signals to the two yielded slightly different image acquisition times. This is not a major problem when using a continuous excitation waveform, such as the sine wave excitation used in the active triangular jet study, but using a square wave and sampling at the rise or fall can lead to the two systems seeing the flowfield at different times with fundamentally different characteristics. Probably the easiest method to avoid this problem is to not sample at the rise of the square wave. This is easy to say in hindsight, however. The observed effect highlights the importance of synchronization and the knowledge of all delays and response times.

5.1.2 Mass Transfer Characteristics

The second goal of this study, to use the optical methods developed to gain insight into the mass transfer characteristics of the actively excited triangular jet and the pulsed swirling jet, was also successfully completed. It was evident that the spatial mode control technique was able to enhance the mass transfer of the active triangular nozzle and to affect the shape of the far field of jet. The most successful mode for this was the counterrotating helical mode, or m=±1, with the area inside the half-concentration contour increasing almost 120% and a very pronounced elliptical shape observed.

It was shown that the pulsed swirl generator jets enhanced the mass transport properties of the swirling jet when compared to the constant jet case. Again, the mode m=±1 appeared to give the best results, by affecting the far field shape as well as increasing the mixing with the ambient fluid. The area inside the half-concentration contour increased by 90% over that of the continuous SGJ case, and an elliptical shape was again observed.

5.2 Recommendations

5.2.1 Planar Mie Scattering Visualization

Because the Mie Scattering system is the simplest to implement, it will continue to be a useful tool, even though the PLIF system can give some better results. However, to improve the PMS system, a new seeder should be developed. The major drawback to the smoke system was the condensation of oil in the flow system. This condensation made the inside of the jet very dirty over time. It also collected on the image collection mirror, which had to be periodically cleaned. Since the oil is not water-soluble, it was difficult to clean these portions of the system. It is recommended that a seeder using sucrose particles be developed, such as that used by Yip (Yip, et al., 1987). Another possibility would be to use TiO_2 particles, generated from $TiCl_4$, though this might lead to serious clogging problems, since the TiO_2 is very difficult to remove.

5.2.2 Planar Laser-Induced Fluorescence Visualization

Though good results were obtained with the Laser-Induced Fluorescence system developed, some changes would improve the system. First, an acetone seeder capable of holding pressure should be developed. Such as system would have allowed flow visualization to be done through the side jets of the swirl jet facility, even using the pulsed valves. The small orifices in the valves caused the flow system to fully pressurize to the supply pressure, which the seeder could not contain. Had the seeder been able to contain the supply pressure, the entire system could have been pressurized and visualization measurements conducted by seeding the side jets. The seeding container should also be placed in a high-quality constant temperature bath to ensure a constant seeding density.

Another possible improvement would be to modify the system to collect absolute mixture fraction data, relative to the nozzle exit, rather than the mixture fraction relative to the centerline value on the plane. This would require the measurement of the laser output for each plane, since the excimer laser has shot-to-shot power variations as well as a decay in laser power over time. The relationship between the intensity across the laser sheet and the measured laser output would also have to be determined. With the improved seeder described above to minimize the seeding variations, the absolute mixture fraction should be obtainable.

5.2.3 Pulsed Swirl Generator Jet Experiments

The study of the actively controlled swirling flows is at the beginning stages and much more can be done to try to increase the degree of control and amount of mixing the pulsing can achieve. For further tests, the low frequency solenoid valves should be replaced, either with high speed valves that can respond to frequencies up to or greater than 100 Hz, or with valves that will respond to a sinusoidal excitation by opening to a fraction corresponding to the amplitude of the excitation waveform. Either of these could yield potentially interesting results.

Another facet of the flow which could be studied is the effect of running the single wave excitation modes, in this case m=1 and m=0.5, in the same direction as the direction of fluid injection by the swirl generator jets. This study only looked at the single wave excitation modes running counter to the direction of fluid injection.

Finally, the swirling flow visualization work should be extended to include visualization of the fluid through the side jets and through an added central fuel tube. The case with the central fuel tube leads to application of the pulsed side jet technique in today's coannular swirl stabilized combustors.