# *Chapter 8 : Conclusions*

An existing flow velocity measurement system was modified and tested during this research. The system used a measurement technique referred to as Doppler Global Velocimetry. In this technique, velocities within a planar data area are measured in a single measurement realization. The Doppler Global Velocimetry technique uses a laser to generate a sheet of laser light, cameras to view seed particles passing through the sheet of laser light and an iodine cell which acts as a molecular filter to measure the Doppler shift of the light scattered by the moving particles. The particular system discussed in this research was designed to measure three non-orthogonal velocity components and convert this data into velocity components in a desired coordinate frame. This system used discoveries by previous researchers as well as adapting the technique to the specific requirements needed for the system to operate in the Virginia Tech Stability Wind Tunnel and with the Dynamic Plunge Pitch and Roll (DyPPiR) apparatus.

The following improvements were made to the VT DGV system over the course of this research:

- Iodine cells were converted from a cold finger arrangement to vapor limited
- Malfunctioning 16-bit digital camera was replaced with a new camera
- A new calibration wheel system was designed, calibrated, and used in tests of the VT DGV system
- Improvements were made to the procedure used to measure the Euler angles for each of the camera modules

- Thorough review of data reduction procedure was made and errors were corrected
- New procedure to calculate the unshifted laser optical frequency was implemented
- New procedure to measure the wave number of the laser pulses used to acquire velocity data was developed and implemented

Several hardware problems were encountered during this research. These problems included:

- Nd:YAG laser was damaged while being shipped back to Virginia Tech after receiving service at manufacturer
- Poor performance of the Nd:YAG laser hampered every attempt to acquire iodine cell calibration images and velocity images
- Laser consistently had problems with frequently resetting and with the large changes in the optical frequency occurring over time
- Ice crystals began to form on the imaging surface of one of the three cameras after it had been on for one hour
- Positions of the camera modules moved over time
- Iodine cell calibrations acquired by one of the camera modules were offset compared to the calibrations acquired by the other two modules
- Insufficient seed particle density in the data plane prevented velocity data in the wake of the 6:1 prolate spheroid model from being acquired
- All problems still exist despite attempts to correct them

The following conclusions can be made about the calibration wheel data acquired during this research:

- Only one of the three sets of velocity data was acquired from the calibration wheel was reducible
- The same general trends present in velocities calculated from angular velocities were observed in the reduced calibration wheel data acquired from the VT DGV system
- The magnitudes of the velocities measured by the VT DGV system were generally significantly higher than those calculated from angular velocities.
- Large fluctuations were present in the velocities measured by the VT DGV system
- Poor laser performance and problems with acquired iodine cell calibrations are most likely causes of the bias in magnitudes and large fluctuations observed in the reduced calibration wheel data

- Average uncertainties for the calculated velocity components were: $\omega V_x$ = 14.076 m/s, $\omega V_y$ = 32.743 m/s, and $\omega V_z$ = 3.562 m/s
- Largest sources of uncertainty in the calculated velocities were the changes in optical frequency calculated from the measured transmission ratios

The following suggestions were made to possibly improve the performance of the VT DGV system in the future:

- The hardware problems encountered with the VT DGV system need to be addressed.
- The problems with performance of the Nd:YAG need to be corrected or the laser needs to be replaced.
- The malfunctioning digital camera needs to be replaced.
- Modifications suggested in the paper published by Meyers *et al* in 2001 should be implemented, including adding a fourth camera module to monitor spatial and temporal variations in the laser pulses output by the laser.
- Perform additional tests to determine the best location and method for injecting seed particles into the wind tunnel
- Simplify the setup and repositioning of the system to make it easier to acquire DGV data at different locations along the model being tested.
- New windows, made of optical quality glass, need to be made for firing the laser into the test section of the Virginia Tech Stability Wind Tunnel and for the camera modules to view the data area.
- The windows for firing the laser into the test section will need to be made to withstand the high power output of the laser. Finally a method to measure the direction of laser propagation needs to be developed.

The VT DGV system has the potential to become a successful and very useful measurement tool. The value of having a system capable of instantaneously measuring a plane of velocities is obvious. The Doppler Global Velocimetry technique is still a fairly new technique and improvements continue to be made. While the results of this research were admittedly less than satisfactory, significant improvements were made to the system and a better understanding of what needs to be done to improve the performance of the system was gained.

*References*