AN EVALUATION OF PRELIMINARY DOPPLER GLOBAL VELOCIMETRY MEASUREMENTS

by

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Doppler Global Velocimetry (DGV) is a new and evolving method for making aerodynamic measurements. The technique, which was invented at Northrop Research and Technology Center, is currently undergoing development and evaluation at the NASA Langley Research Center (LaRC). Future DGV system applications planned include F-18 flight tests at NASA Ames and wind tunnel investigations at LaRC.

DGV is a very attractive technique since it potentially offers the capability for making simultaneous three-component velocity measurements within a flow plane region. The basic operating principle is very simple. References 1-4 provide a more detailed description. In summary, a laser is used to generate a plane of light within the flow field region of interest. Particles, or seeds, present in the moving flow scatter this light with a frequency determined by the Doppler effect. Scattered light frequency measurement from a specific direction can thus allow single flow velocity component identification. This frequency discrimination is performed using an optically transparent Absorption Line Filter (ALF) which has a transmission behavior similar to that shown in Figure 1. The laser is normally tuned to operate in the mid (5th mode location) linear ALF transmission range. Flow field velocity changes, which cause scattered light frequency changes due to the Doppler effect, are simply measured as intensity levels by a CCD camera viewing the illuminated flow through the ALF. A second CCD camera views the same flow region and is used to identify intensity variations which have nothing to do with Doppler frequency effects. The signal from each camera is acquired by processing electronics which provide as output a normalized image describing the velocity within the illuminated flow. To make three-component measurements three camera and ALF sets are required to view the light sheet region from three separate directions. A simple one-component system schematic is shown in Figure 2.

A number of very basic tests have been performed in the past to identify DGV performance and capability. Recently, however, a more challenging investigation using a one-component DGV system was conducted on a thin 75 degree swept delta wing in the NASA LaRC Basic Aerodynamic Research Tunnel (BART). It is the purpose of this paper to discuss and evaluate the BART test results and to provide recommendations as necessary for future DGV test activities.

Initial BART results evaluations were somewhat discouraging. Figure 3 shows a direct comparison between DGV and baseline data for the flow velocity (resolved into the measured DGV direction) along a horizontal line through each wing vortex core. In this figure, the solid continuous line represents baseline data, from references 5 and 6, and the discontinuous lines represents DGV data. The DGV data is not continuous since seeds or particles were not present at all points in the flow. Two points of concern surface from the comparison made in Figure 3. Specifically, the DGV data shows rapid high frequency variations and the general velocity trends appear incorrect.

Careful data examination indicates that the two camera images were not exactly aligned. This misalignment can result in the introduction of high frequency variations during normalization. Camera position differences, CCD array differences or ALF image distortions may have introduced the alignment problems. It appears likely that careful camera aiming or image processing (FFT or Convolution) procedures can be used to remove the image variations.

Output simulations were performed to identify potential BART DGV velocity trend problems. To explore the possibility that the laser may have been improperly tuned, a simple nonlinear ALF transfer function model was applied to the baseline data to generate simulated DGV output data. Direct comparison of these results with actual DGV data suggests that the DGV system was indeed operating in a nonlinear condition during the BART investigation. An elaborate and complex scheme was developed to "correct" the DGV data for nonlinear effects. Figure 4 shows a comparison between the corrected and baseline results. As can be seen these results compare much better than those previously shown in Figure 3. Unfortunately some differences, which are likely due to the difficulty associated with properly correcting the nonlinear source data, still exist.

In summary, a review of DGV data obtained during wind tunnel tests on a 75 degree swept delta wing was performed. High frequency variations observed in normalized image files are attributed to image alignment problems. Unfortunately, initial DGV velocity data compared poorly with baseline reference data. Nonlinear DGV system operation during the tests is the likely source of this problem. Corrected data compares much more favorably and suggests that DGV is a valid measurement technique. Future DGV investigations should include a method or means for monitoring laser frequency relative to the ALF transfer function behavior.

References

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2) Meyers, J.F. and Komine, H., "Doppler Global Velocimetry A New Way to Look at Velocity," ASME Fourth International Conference on Laser Anemometry, Cleveland, Ohio, Aug. 1991.

3) Komine, H. and Brosnan, S.J., "Instantaneous Three-Component Doppler Global Velocimetry," ASME Fourth International Conference on Laser Anemometry, Cleveland, Ohio, Aug. 1991.

4) Meyers, J.F., Lee, J.W. and Cavone, A.A., "Signal Processing Schemes for Doppler Global Velocimetry," IEEE 14th International Congress on Instrumentation in Aerospace Simulation Facilities, Rockville, Maryland, Oct. 1991.

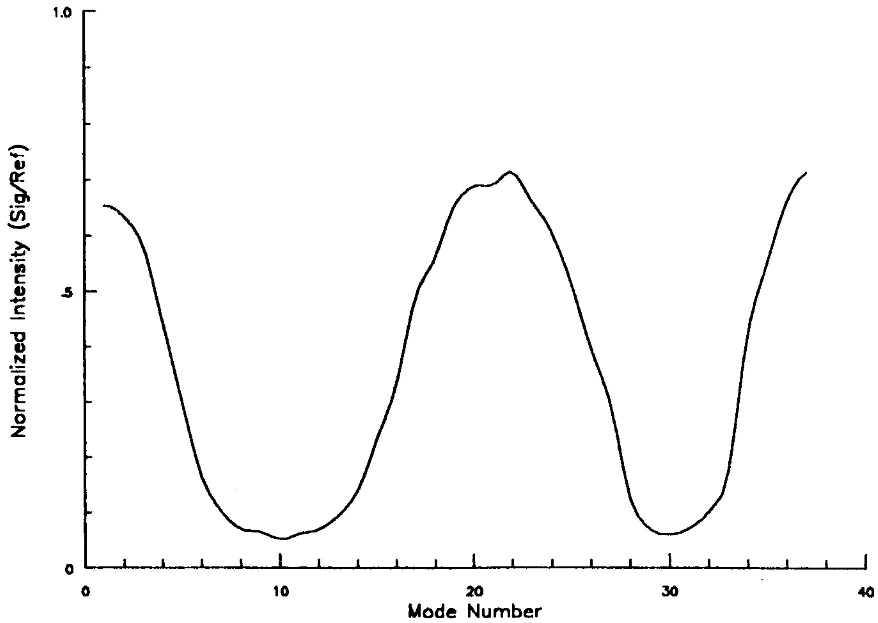

Figure 1. Example of an Absorption Line Filter (ALF) transfer function.
(The vertical axis represents normalized transmission and the horizontal axis represents laser frequency in terms of mode number.)

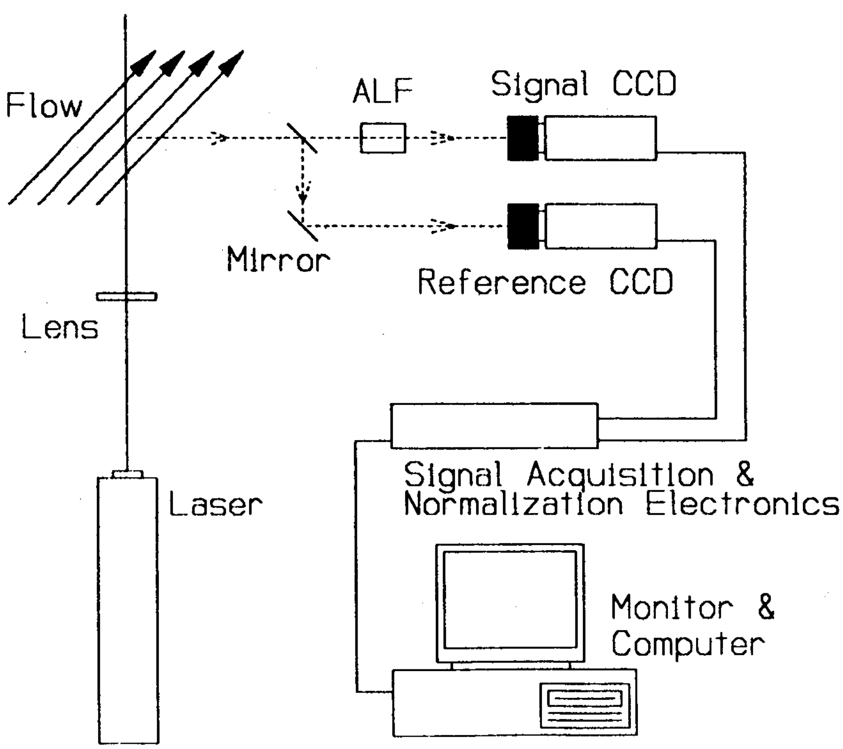

Figure 2. A schematic diagram of a one-component DGV system.

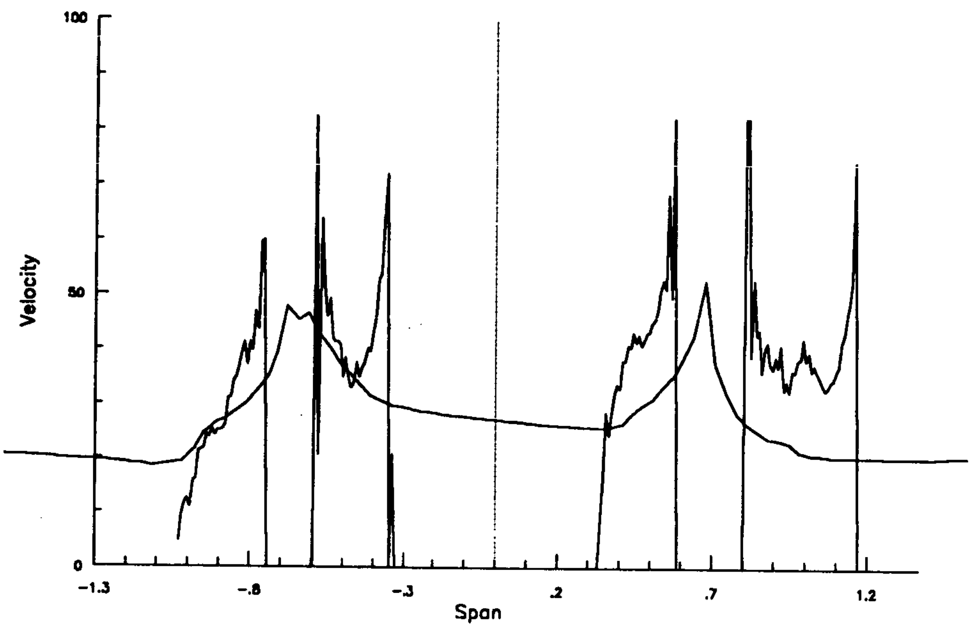

Figure 3. Comparison between initial DGV and baseline data.
(The vertical axis represents velocity in meters/second and the horizontal axis represents normalized wing span.)

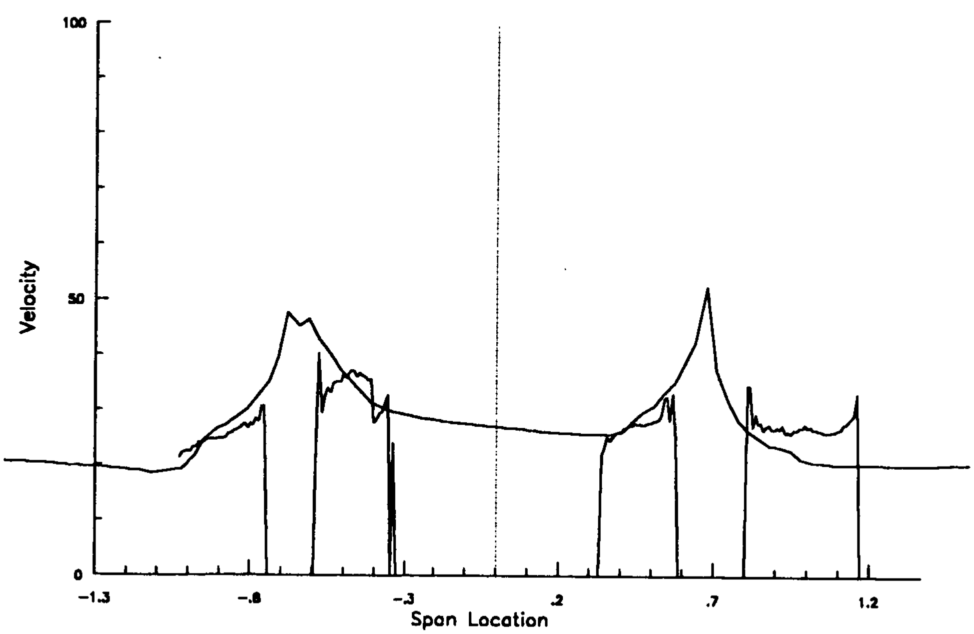

Figure 4. A comparison between corrected DGV and baseline data.
(Axes are as described in figure 3.)