DOPPLER GLOBAL VELOCIMETRY

Jim Usry
NASA Langley Research Center
Hampton, VA 23665

The Langley Research Center is initiating a program to develop a Doppler Global Velocimeter (DGV) for application in the High-angle-of Attack Technology (HATP) Program. The Flight research instrument system will make non-intrusive, multicomponent velocity measurements of the vortical flow field around an aircraft in flight. Modern high performance aircraft such as the F-18 and the futuristic DARPA-USN X-31 operate at extreme maneuvering conditions and high angles of attack. Typically these aircraft shed vortices from wing leading edges and from slender forebodies to produce large increments of lift when operating at high angles-of attack. While the vortices may be beneficial, they may also interact with the airframe or other external systems to produce buffet, fatigue-related structural problems, and other undesirable flow dynamics. Existing theoretical models do no adequately simulate the flow dynamics under these conditions, and further development is restricted due to lack of detailed experimental data. Wind tunnel facilities equipped with non-intrusive, laser-based measurement systems can provide most of the experimental data needs, but in a highly dynamic flow environment, local flow conditions around scaled wind tunnel models will differ from those on the full scale flight vehicle. For these reasons, there is a growing need for a comprehensive experimental database (flight as well as wind tunnel data) to validate computed results and to aid in the further development and refinement of computational fluid dynamic (CFD) models.

A perennial problem in flight testing has always been to measure the fluid flow parameters using surface-mounted probes without interfering with the local flow conditions. This problem is complicated further when measurement systems are required to measure off-body, complex, and highly dynamic three-dimensional vortical flows in the disturbed flow field of an aircraft flying at high angles of attack. Probe based measurement techniques are obviously not suitable for this application, and thus, non-intrusive techniques are essential to produce reliable and accurate information.

Non-intrusive measurement systems have been used in wind tunnels since the mid-70's to measure flow above models at high angles of attack. The first measurements were made using a two component, fringe-type laser velocimeter to measure the separation bubble behind a NACA-0012 airfoil. Later work measured the vortical flow field above a 75-degree delta wing using an orthogonal three-component, fringe-type laser velocimeter. This led to the first flow field investigation on a configuration model (YF-17) at high angles of attack. The three velocity component measurements of the flow at 25-degrees angle-of-attack clearly showed the complexity of the burst vortex with reverse flow regions and turbulence intensities approaching 30-percent in all three directions. The flow was also found to be completely separated above about 50% of the wing, indicating that the majority of the lift was vortex generated.

Wind-tunnel studies such as the YF-17 experiments must use fixed angle-of-attack settings, with the tunnel held at constant flow conditions during the eight hours required to scan a measurement plane normal to the model centerline. While the results provide great insight into the flow mechanisms at the chosen angle-of-attack, the measurement technique is not suitable for measuring changes to the flow field during dynamic maneuvers such as would occur in flight. To do that, the instrumentation system must measure the entire data field simultaneously in a short enough time interval to effectively freeze the flow field. Furthermore, the system must be lightweight, compact and flight certifiable to operate on a high performance aircraft such as the F-18.

The DGV, when developed, will provide a means to obtain airborne experimental data to evaluate and refine computational fluid dynamic models being developed by NASA and to correlate with wind-tunnel data sets. The primary use of the instrument system will be to provide a flexible research tool to map the 3-D velocity field at various locations around an aircraft during high angle-of-attack maneuvers at subsonic, transonic, and supersonic speeds. Other potential applications may include shock definition and interactions, external stores flow interactions, rotary flow field definition, non-steady flow field definition, measurement of inlet and duct flow fields, and measurement of hypersonic flow fields in flight.