Aerodynamic measurement technology

University of Florida researchers presented a microelectromechanical systems-based capacitive wall shear stress sensor for turbulence measurements. It consists of a tethered floating element structure with comb fingers for electromechanical transduction, and employs silicon-micromachining techniques to develop a metal-plated, differential capacitive floating-element-based design. A shear-induced sensor motion results in a proportional capacitance change, measured as a voltage. A simple fabrication process with two lithography steps is used, with deep reactive ion etching on a silicon insulator wafer. The sensor exhibits a linear sensitivity up to the testing limit of 1.1 Pa and a bandwidth of 6.2 kHz. The device has the largest dynamic range and lowest noise floor of any MEMS shear stress sensor to date.

The unsteady pressure-sensitive paint (PSP) technique developed by the Japan Aerospace Exploration Agency (JAXA) was applied to visualize changes in pressure distribution on a wing in flutter. Fast-response anodized-aluminum PSP was coated on a thin aluminum half wing model for flutter measurements. The model was illuminated by a high-power blue laser diode, and its PSP luminescence was measured by a CMOS high-speed camera at 4,000 frames per second. Time-series PSP results revealed a limit cycle oscillation (LCO) in which unsteady pressure behavior was observed. Downward deformation of the wing caused positive angle of attack at the wing tip because of the swept-back angle, so that lambda-shaped shock structure was clearly observed. No shock waves were observed in upward deformation cases where the angle of attack induced by the deformation was negative. Continuous time-series results produced by the unsteady PSP technique are helpful in understanding the unsteady behavior of the global pressure field, including shock waves in the LCO phenomena.

JAXA and Tohoku University jointly developed an innovative technique to measure the spanwise distribution of lift and drag on a wing by stereo particle imaging velocimetry (PIV). The 2D Poisson equation for pressure is solved using PIV velocity data in a measurement plane perpendicular to the freestream direction, yielding the static pressure distribution. Using the wake integral method, spanwise distributions of profile and induced drag and lift are obtained based on the derived pressure data and the three-component velocity data from the PIV.

This technique was applied to wind tunnel tests of a Japanese regional jet, the MRJ (Mitsubishi Regional Jet), to support the aerodynamic design. The technique provides profile and induced drag distributions, which cannot be supplied by conventional balance measurements. The profile drag and induced drag and lift data generated by aerodynamic components (winglets, high-lift devices, engine nacelle, and so on) have proven useful in aerodynamic design studies.

Researchers at the Laboratory for Turbulence Research in Aerospace and Combustion (LTRAC) at Monash University in Melbourne, Australia, led by Julio Soria, and at the Laboratory for Mechanics Lille (LML) at the Ecole Central de Lille, France, led by Michel Stanislas, have undertaken the first 3C-3D (three-component three-dimensional) velocity vector field measurements using accelerated multiple-line-of-sight SMART-based Tomo PIV (developed at LTRAC) of a turbulent boundary layer. The measurements produced instantaneous quantitative 3C-3D velocity vector field measurements in the boundary layer, revealing vortices and other flow structures.

Researchers at Ohio State and Iowa State universities developed a MHz-rate nitric oxide planar laser-induced fluorescence imaging system. The system was demonstrated in the 31-in. Mach 10 wind tunnel at NASA Langley, where it was used to study the time evolution of the transition to turbulence in supersonic boundary layers. In a separate experiment, Langley researchers have demonstrated non-invasive measurement of 2D oblique-shock strengths (that is, pressure change) with two independent optical methods, Doppler global velocimetry and laser-induced thermal acoustics, finding excellent agreement between the two approaches.