

## Aerodynamic measurement technology

Iowa State developed a lifetime-based molecular tagging thermometry technique for achieving simultaneous measurements of droplet size and transient temperature distribution within icing water droplets. A pulsed laser was used to tag phosphorescent 1-BrNp-M $\beta$ -CD-ROH molecules premixed within a small water droplet. Laser-induced phosphorescence was imaged at two successive times after the same laser excitation pulse. Droplet size was determined instantaneously from the phosphorescence images; the transient temperature estimated from the intensity ratio of phosphorescence image pairs.

The Japan Aerospace Exploration Agency developed an innovative high-resolution unsteady pressure imaging technique using pres-

sure-sensitive paint (PSP). Time-series PSP intensity of identical pixels among images acquired by a high-speed camera was processed to the amplitude and phase map of the frequency domain by introducing the fast Fourier transform to the PSP data reduction algorithm. Typical spatial resolution of the measurements corresponded to the camera pixel size of  $\approx 0.1$  mm and minimum pressure resolution, dependent on the acquired PSP intensity, resulted in  $\approx 10$  Pa pressure resolution for an unsteady component in the present application. A future primary application area of this imaging technique will be an unsteady flow field coupled with an aeroacoustic field.

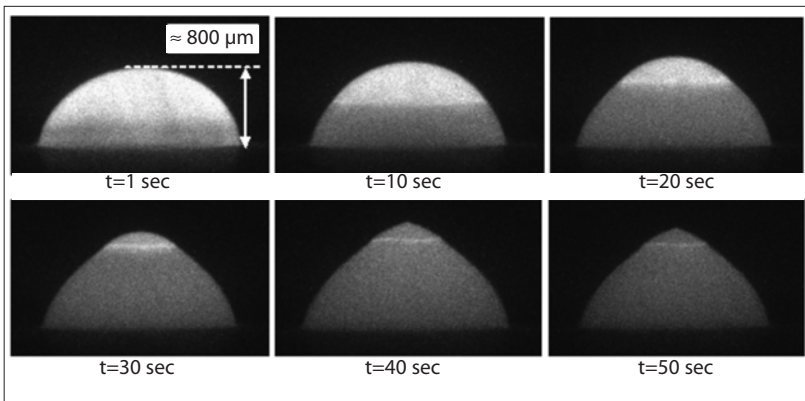
A global luminescent oil-film skin-friction meter was developed at Western Michigan University for quantitative skin friction diagnostics in complex flows. The evolution of the oil thickness pattern was measured by imaging the oil's luminescent intensity, and the data reduction for skin friction was based on a variational solution for the projected thin-oil-film equation on the image plane. The normalized skin friction fields were obtained in junction flows and flows over delta and double-delta wings, and low-aspect-ratio rectangular wings.

Researchers at Southern Methodist University (SMU) have achieved whispering gallery mode resonances in polymer microspheres with a Q-factor as high as  $10^7$ , allowing detection of morphology-dependent optical resonance shifts as small as 0.1 pm. Force sensitivities on the order of a pico-Newton are feasible using hollow polydimethylsiloxane microspheres. Based on these findings, SMU and Michigan Aerospace have teamed up to develop a highly sensitive seismometer.

Auburn University researchers have developed a high-speed 3D flow visualization technique capable of acquiring 3D images in tens of microseconds. The technique is based on the scanning and subsequent imaging of a laser sheet through the flow field at very high speeds using a home-built MHz rate pulse burst laser system, galvanometric scanning mirror, and high-speed camera. Flow images were taken in a turbulent jet with a Reynolds number of 6,700. Over this period of time, the flow moved less than one pixel.

A NASA Langley and NASA Ames team has developed and tested an optical system to measure structural deformation of full-scale rotorcraft blades in a wind tunnel environment (up to 123 kt). In initial testing at the Ames National Full-Scale Aerodynamics Complex, a tow-camera version of the system was used to study one azimuth quadrant of a single rotor blade rotating at 6.5 Hz.

The system uses image processing and photogrammetry on multiple digital images coupled with synchronized xenon pulsed light sources to obtain time-resolved data at any desired azimuth of the spinning rotor. Eight digital cameras are being integrated to measure time-resolved blade deformation over the full range of azimuth. Expected measurement accuracies for flow-induced blade deflection and twist are 0.5 mm and 0.1 deg respectively. Engineers at Arnold Engineering Development Center installed a stereoscopic particle image velocimetry (PIV) system in the 4T aerodynamic wind tunnel to measure velocities in the wake of a 1/20th-scale F-15 model. Stereo-PIV, a nonintrusive velocity measurement technique, images the displacement of laser-illuminated seed particles to measure three-component velocities. Data sets obtained in Mach 0.4 flow at eight different model attitudes showed excellent agreement with CFD solutions in the counterrotating wake structures.  $\blacktriangle$



A technique developed at Iowa State shows the phase-changing process within an icing water droplet (initial temperature at 21.5 C) placed on a cold aluminum test plate (-3.0 C). The "bright" region represents the liquid phase of water; the "dark" region at the bottom indicates the ice phase.

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by **Dominique Fourquette** and the **Aerodynamic Measurement Technology Technical Committee**