Adaptive Structures

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The last year of the century has seen across the board advances in adaptive structures. Many successful adaptive system demonstrations took place this year. NASA-Langley scientists controlled turbulent boundary layer noise on large panels in the AEDC (USAF) wind tunnel, at Mach 0.8 and 2.1, reducing total radiated sound 10 - 15 dB at resonances, and 5 - 10 dB over 150 to 800 Hz. MIT researchers tested a $1/6^{th}$ scale CH47 helicopter blade incorporating active piezoelectric fiber composites and a piezoelectric-actuated tab that produced ±80% thrust variations, reducing 80% of vibrations to the swash plate assemblies. Georgia Tech researchers reduced tail buffet-induced vibrations by over 85% in wind tunnel tests on a $1/16^{th}$ scale model of an F-15 using an offset piezoceramic stack actuator. Boeing, General Dynamics and Penn State researchers working on DARPA's Smart Aircraft and Marine Propulsion System demonstration are developing a mission-adaptive aircraft engine inlet and a quieter marine propulsor using a shape memory alloy actuator capable of 20,000 lbf and 6 inches of displacement. The Air Force Research Lab and CSA Engineering successfully flew two whole-spacecraft isolation systems, reducing structural launch loads by as much as 85%. Vanderbilt researchers have created walking insect-like robots, using piezoelectric transducers as drivers.

Others are addressing very large aperture lightweight optics for future space applications. Researchers at the University of Kentucky used electron guns to provide high-resolution control of a membrane mirror on an inflatable structure, eliminating electrodes and wires. Researchers at AFIT and Virginia Tech are combining non-woven, multi-axial reinforced 3-D fabrics with shape memory materials to enable control of inflatable structure deformations in virtually all directions. NASA MSFC researchers are also modal testing the inflatable Solar Orbital Transfer Vehicle.

Researchers at Arizona State and Texas A&M universities developed improved mathematical models of composite structures with embedded smart material actuators. An aeroelastic simulation program of rotorblade vibration reduction developed at University of Michigan agrees within 20-40% with windtunnel experimental data gathered at Aeroflight Dynamics Lab of the Army for a piezo-actuated rotorblade flap.

Using frequency rectification to increase power densities, UCLA researchers developed compact smart-materials based motors that used piezoelectric inchworm motion implemented with MEMS components while Penn State devices used both wedge and roller locking. University of Michigan actuators used internal amplification of piezoelectric motion to generate high work output per volume. Other researchers at Georgia Tech and MIT are pursuing hybrid piezoelectric-hydraulic pumps.

Responding to system and actuator designers, many improved smart materials were pursued this year. Breakthroughs occurred in shape memory alloys, with researchers from the universities of Minnesota and Maryland discovering magnetically activated materials (as opposed to thermally activated). UCLA researchers have developed a

functionally graded SMA thin film that produces the two way effect and can be cycled at frequencies near 100 Hz. Penn State researchers discovered irradiated PVDF copolymers that exhibit large strains (5%) and coupling coefficients. Research continues across the country on single piezoelectric crystals first developed at Penn State.

Small was also big this year. At Auburn University, researchers designed and prototyped piezoceramic actuators for adaptive bullets and halved the weight of their adaptive stabilators for microUAV applications. Honeywell also prototyped a miniature vibration isolation system for spacecraft component isolation, consisting of a passive and active stage, a microcontroller, and a MEMS sensor within a one-inch cube.

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