Structures

The nonprofit National Institute of Aerospace (NIA) has been formed by NASA-Langley to carry out cutting-edge aerospace and atmospheric research, develop new technologies for the nation, and help inspire the next generation of scientists and engineers. NIA will offer masters' and doctoral degrees in science and engineering through local campuses and distance learning. It will become a catalyst for economic development by stimulating new intellectual property commercialization and facilitating new business opportunities.

Arizona State University researchers are developing a structural health-monitoring procedure for characterization and detection of multiple delaminations in composite structures. The procedure combines refined analysis techniques with experiments based on laser vibrometry and noncontact air-coupled ultrasonic equipment. Also under development is an embedded distributed sensor architecture that mimics biological neural systems to detect acoustic energies released during delamination "breathing" under service loads. Comparisons of voltage outputs from healthy and damaged structures are used to signal the presence of seeded delaminations.

The Air Force Institute of Technology is examining projects dealing with F-16 limit cycle oscillation characterization from nonlinear flutter analyses, completed weight and configuration studies for joined-wing sensor craft, efficient function and gradient matching response surface algorithms, active control of adaptive optical membranes for flight demonstration and characterization of an inflatable rigidizable structure, health-monitoring to predict damage locations within space substructures, high-energy impact studies, and high cycle fretting fatigue of blade/disk attachment investigations.

RLV efforts

NASA is developing hot structures technology to improve performance and reduce maintenance of reusable launch vehicle (RLV) structures. Carbon-fiber-reinforced silicon carbide composite body flaps are proposed to be built and flown on the X-37. A body flap subcomponent designed by Materials Research and Design and fabricated by General Electric Power Systems Composites will be thermal-mechanically tested at up to 2,800 F at NASA-Dryden. Because these body flaps need no insulation, 30-50% weight savings compared to insulated structures are achievable. They also require less maintenance, because thermal protection systems are replaced by structural inspection techniques.

New-generation large composite cryogenic fuel tanks have been developed through joint Northrop Grumman and NASA-Marshall efforts to produce safer, more efficient RLVs. Subscale composite tanks will be used with triple-redundant permeation suppression systems to prevent liquid hydrogen cryopumping into the tank’s honeycomb core. After cryogenic tests, tanks will be exposed for nine months to repeated fill/drain and mechanical loading cycles to validate tank structure reusability.

Through the Space Launch Initiative, NASA and Boeing successfully demonstrated accurate forming of aluminum isogrid panels for future RLV cryotank applications. The approach was to design, machine, and form isogrid panels with a structurally efficient T-cap configuration. The final panels are made of 2219 aluminum and L277 aluminum-lithium. Postforming inspection verified successful demonstrations of these innovative designs and low-risk processes.

ARO projects

Under Army Research Office (ARO) sponsorship, the Mechanical and Nuclear Engineering Dept. at Pennsylvania State University is developing new classes of high-authority smart structures to simultaneously isolate and control multimode vibrations. Primary areas are: creating/innovating piezoelectric materials-based smart pad concepts and design schemes for multimode, multifrequency, adaptable operations; developing a new understanding of how vibration isolation actions could be compromised by vibration control actions in an actuator configuration; and developing control methodology using high-authority characteristics of piezoelectric materials and combined effects of different active and passive materials.

The mechanical engineering departments at the University of Michigan and Michigan State University are conducting a collaborative research effort called Model Reduction Techniques for Large-Amplitude Vibrations of Complex Nonlinear Structures. Major objectives are to systematically generate reduced-order models for large-scale nonlinear structures such as rotorcraft blades through developments of nonlinear modal analyses; to use these models to effectively predict vibrations of structural components and jointed assemblies and to assess attendant reliability and durability using minimally sized models; and, ultimately, to enable fast, reliable high-fidelity simulations of structural and acoustical responses of rotorcraft and ground vehicle structures.

The University of Michigan’s Aerospace Engineering Dept. is conducting a project entitled...
Exploring Embedded Actuation in Advanced Helicopter Rotor Blades. This effort investigates new and effective ways of using embedded anisotropic piezoelectric actuation to improve blade response, vibratory hub loads, and rotor performance in advanced helicopter rotor blades. The main objectives are to develop active aeroelastic analyses that account for 3D electroelasticity effects of anisotropic piezocomposite actuators embedded in composite blades; explore new methods of integral blade actuation and active blade aeroelastic tailoring to minimize hub vibratory loads; and experimentally bench-test selected actuation concepts.

Another ARO project in this department is entitled Active Control for Simultaneous Noise and Vibrations Reduction in Rotorcraft Employing Active Materials-Based Actuation. Research involves numerical simulations of noise and vibration reduction in rotorcraft using partial-span actively controlled trailing-edge flaps with dual-flap configurations. This code involves vibration and noise simulations based on the same aeroelastic model. Wind tunnel and flight tests show that when vibrations are reduced using active control, in many cases noise levels tend to increase, and vice versa.

Other activities

NASA-Glenn research is developing revolutionary jet engine concepts to meet the increasingly demanding and challenging next-generation requirements. The exoskeletal engine concept eliminates shafts and disks completely, while attaching blades in spanwise compression to a rotating casing. This concept offers many benefits, such as lighter weight, improved fatigue life, foreign object damage minimization, and improved fan efficiency. Computational simulation capabilities are available.

Another Glenn project deals with instabilities of composite shell structures under static and dynamic loads. Parameter variabilities are treated by probabilistic dynamic buckling analyses. The analysis updates material properties, temperatures, deformations, and structural damage. Combined capabilities of multidisciplinary composite mechanics, dynamic structural analysis, and probabilistic simulations are needed, and the EST/BEST protocol was used to evaluate probabilistic composite shell dynamic buckling.

The AFRL Air Vehicles Directorate’s Structures Div. is applying nondeterministic methods to airframe analysis, design, and certification. Relevant projects include experiments to measure the variability of bolted joint properties for predictive joint model validation, exploring nonlinear aeroelastic system sensitivities to properties and boundary conditions, and formulating supporting roles for uncertainty quantification in airframe systems engineering. A collaborative project with Vanderbilt University to pursue the reliability-based design of hot structure health-monitoring systems was initiated.

The NASGRO 4.0 code for fracture mechanics and fatigue crack growth analysis received an R&D 100 award as one of the year’s 100 most technologically significant new products. It was developed jointly by NASA-Johnson and Southwest Research Institute with additional support from the FAA and 14 major aircraft, rotorcraft, and gas turbine engine manufacturers from nine countries. NASGRO is the standard fracture control software used by all NASA centers and by many contractors and international partners.

FAA is supporting research programs in characterization testing of impact-damaged sandwich structures. This research was spurred by uses of sandwich structures in general aviation airplanes and in older commercial aircraft. Damage tolerances of impact sandwich panels were evaluated via compression-after-impact tests. The data are scattered around a hypothetical degradation curve independent of impactor diameters.

Lockheed Martin Aeronautics is developing new efficient aircraft structures certification technologies in collaboration with Boeing and Northrop Grumman. A joint program will provide streamlined structural analyses for rapid air vehicle internal loads model development, sizing, and correlation to full-scale tests. As a Composite Affordability Initiative working member, Lockheed Martin is focusing mainly on development of enabling 3D preform bonded joint technologies for highly loaded unitized structures. Validation will be provided by vertical tail component certification scenarios.