Materials

Damage Detection and Self-Repair in Inflatable / Deployable Structures

Integrated sensors and self-repairing materials provide structural health management.

NASA's Jet Propulsion Laboratory, Pasadena, California

Inflatable / deployable structures are under consideration for applications as varied as expansion modules for the International Space Station to destinations for space tourism to habitats for the lunar surface. Monitoring and maintaining the integrity of the physical structure is critical, particularly since these structures rely on non-traditional engineering materials such as fabrics, foams, and elastomeric polymers to provide the primary protection for the human crew. The closely related prior concept of monitoring structural integrity by use of built-in or permanently attached sensors has been applied to structures made of such standard engineering materials as metals, alloys, and rigid composites. To effect monitoring of flexible structures comprised mainly of soft goods, however, it will be necessary to solve a different set of problems — especially those of integrating power and data-transfer cabling that can withstand, and not unduly interfere with, stowage and subsequent deployment of the structures. By incorporating capabilities for self-repair along with capabilities for structural health monitoring, successful implementation of these technologies would be a significant step toward semi-autonomous structures, which need little human intervention to maintain. This would not only increase the safety of these structures, but also reduce the inspection and maintenance costs associated with more conventional structures.

A series of proof-of-concept technology sensing and self-repair technologies have recently been developed and tested individually, for future integration into a full health management system for inflatable / deployable structures. With further development, these technologies could be applied individually or as part of an entire system, depending on the particular architecture of the structure or on the specific mission needs. The technologies include:

- Arrays of thin-film capacitive or inductive sensors, made of a flexible circuit material that can be integrated into an inflatable / deployable structure for use in detecting the location and extent of damage. Damage manifests itself as changes in inductance or capacitance in elements of the sensor array.
- Strain gauges made from thin films of amorphous silicon for monitoring the integrity of thin, flexible structures. To reduce the amount of wiring required, thin-film transistors are used to construct an addressable, matrixed array of sensors allowing selection and readout of specific sensors in the array.
- Wireless sensors and passive (no-power) radio-frequency identification sensor tags to provide additional sensing capabilities such as strain sensing, temperature sensing, and impact or leak detection, without the need for data and power cables.
- Self-repairing elastomeric materials (such as those used to construct the bladder of a habitat), which incorporate microcapsules filled with a monomer resin and a small amount of a polymerization catalyst. Upon damage to the material, some of the capsules burst and release the monomer, becoming polymerized after making contact with the embedded catalyst and thus effecting repair of the damage.
- Sensory and self-repair features will eventually be combined into the structure to effect a unified structural health maintenance system. Sensors will alert humans to initial damage and will monitor the self-repair process, to indicate whether there is a need for human intervention for inspection and / or repair.

This work was done by Erik Brandon of Caltech, George Studor of NASA Johnson Space Center, David Banks and Mark Curry of Boeing Phantom Works, Robert Broccato of Sandia National Laboratories, Tom Jackson of Penn State University, Kevin Champaigne of Invocon, Stan Woodard of NASA Langley Research Center, and Nancy Sottos of the University of Illinois at Urbana-Champaign for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44519

Polyimide / Glass Composite High-Temperature Insulation

This composite was found to exhibit an unexpectedly high degree of fire resistance.

Langley Research Center, Hampton, Virginia

Lightweight composites of RP46 polyimide and glass fibers have been found to be useful as extraordinarily fire-resistant electrical-insulation materials. RP46 is a polyimide of the polymerization of monomeric reactants (PMR) type, developed by NASA Langley Research Center. RP46 has properties that make it attractive for use in electrical insulation at high temperatures. These properties include high-temperature resistance, low relative permittivity, low dissipation factor, outstanding mechanical properties, and excellent resistance to moisture and chemicals. Moreover, RP46 contains no halogen or other toxic materials and when burned it does not produce toxic fume or gaseous materials.

The U. S. Navy has been seeking lightweight, high-temperature-resistant elec-