



Hybrid Composite Cryogenic Tank Structure

A number of materials can be used to produce external and internal layers of the structure.

Marshall Space Flight Center, Alabama

A hybrid lightweight composite tank has been created using specially designed materials and manufacturing processes. The tank is produced by using a hybrid structure consisting of at least two reinforced composite material systems. The inner composite layer comprises a distinct fiber and resin matrix suitable for cryogenic use that is a braided-sleeve (and/or a filament-wound layer) aramid fiber preform that is placed on a removable mandrel (out-fitted with metallic end fittings) and is infused (vacuum-assisted resin transfer molded) with a polyurethane resin matrix with a high ductility at low temperatures. This inner layer is allowed to cure and is encapsulated with a filament-wound outer composite layer of a distinct fiber resin system. Both inner and outer layer are in intimate contact, and can also be cured at the same time. The

outer layer is a material that performs well for low temperature pressure vessels, and it can rely on the inner layer to act as a liner to contain the fluids.

The outer layer can be a variety of materials, but the best embodiment may be the use of a continuous tow of carbon fiber (T-1000 carbon, or others), or other high-strength fibers combined with a high ductility epoxy resin matrix, or a polyurethane matrix, which performs well at low temperatures. After curing, the mandrel can be removed from the outer layer.

While the hybrid structure is not limited to two particular materials, a preferred version of the tank has been demonstrated on an actual test tank article cycled at high pressures with liquid nitrogen and liquid hydrogen, and the best version is an inner layer of PBO (poly-phenylenebenzobisoxazole) fibers with a

polyurethane matrix and an outer layer of T-1000 carbon with a high elongation epoxy matrix suitable for cryogenic temperatures. A polyurethane matrix has also been used for the outer layer. The construction method is ideal because the fiber and resin of the inner layer has a high strain to failure at cryogenic temperatures, and will not crack or produce leaks. The outer layer serves as more of a high-performance structural unit for the inner layer, and can handle external environments.

This work was done by Thomas DeLay of Marshall Space Flight Center.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32390-1.

Nanoscale Deformable Optics

This technology has potential applications in medical imaging, robotics, precision machining, and threat detection.

NASA's Jet Propulsion Laboratory, Pasadena, California

Several missions and instruments in the conceptual design phase rely on the technique of interferometry to create detectable fringe patterns. The intimate emplacement of reflective material upon electron device cells based upon chalcogenide material technology permits high-speed, predictable deformation of the reflective surface to a sub-nanometer or finer resolution with a very high degree of accuracy.

In this innovation, a layer of reflective material is deposited upon a wafer containing (perhaps in the millions) chalcogenic memory cells with the reflective material becoming the front surface of a mirror and the chalcogenic material becoming a means of selectively deforming the mirror by the application of heat to the chalcogenic material. By doing so, the mirror surface can

deform anywhere from nil to nanometers in spots the size of a modern day memory cell, thereby permitting real-time tuning of mirror focus and reflectivity to mitigate aberrations caused elsewhere in the optical system.

Modern foundry methods permit the design and manufacture of individual memory cells having an area of or equal to the Feature (F) size of the design (assume 65 nm). Fabrication rules and restraints generally require the instantiation of one memory cell to another no closer than 1.5 F, or, for this innovation, 90 nm from its neighbor in any direction.

Chalcogenide is a semiconducting glass compound consisting of a combination of chalcogen ions, the ratios of which vary according to properties desired. It has been shown that the applica-

tion of heat to cells of chalcogenic material cause a large alteration in resistance to the range of 4 orders of magnitude. It is this effect upon which chalcogenide-based commercial memories rely. Upon removal of the heat source, the chalcogenide rapidly cools and remains frozen in the excited state. It has also been shown that the chalcogenide expands in volume because of the applied heat, meaning that the coefficient of expansion of chalcogenic materials is larger than 1.

In this innovation, chalcogenide-based cells are addressed (as though they are a memory), and heated and cooled according to well-established criteria. In doing so, the exact size of chalcogenide cell deformation is known and predictable; therefore, the deformation of the reflective surface is, likewise,

known and predictable. Control electronics can also be implemented so that a closed-loop feedback can be maintained. Changing the contents of the chalcogenide memory cells can compen-

sate for any change in environmental effects that might cause a change in optical path. This real-time control provides significant control and stability in use conditions.

This work was done by Karl F. Strauss and Douglas J. Sheldon of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46891

Reliability-Based Design Optimization of a Composite Airframe Component

This methodology accommodates uncertainties in load, strength, and material properties.

John H. Glenn Research Center, Cleveland, Ohio

A stochastic optimization methodology (SDO) has been developed to design airframe structural components made of metallic and composite materials. The design method accommodates uncertainties in load, strength, and material properties that are defined by distribution functions with mean values and standard deviations. A response parameter, like a failure mode, has become a function of reliability. The primitive variables like thermomechanical loads, material properties, and failure theories, as well as variables like depth of beam or thickness of a membrane, are considered random parameters with specified distribution functions defined by mean values and standard deviations.

The cumulative distribution concept is used to estimate the value of the response parameter like stress, displace-

ment, and frequency for a specified reliability. This solution for stochastic optimization also yields the design and weight of a structure as a function of reliability. Weight versus reliability is traced out in an inverted S-shaped graph. The center of the graph corresponds to 50-percent probability of success, or one failure in two samples.

A heavy design with weight approaching infinity could be produced for a near-zero rate of failure. Likewise, weight can be reduced to a small value for the most failure-prone design. Reliability can be changed for different components of an airframe structure. For example, the landing gear of an airliner can be designed for very high reliability, whereas it can be reduced for a raked wingtip.

The design capability is obtained by combining three codes: MSC/Nastran

code (the deterministic analysis tool), the fast probabilistic integration or the FPI module of the NESSUS software (the probabilistic calculator), and NASA Glenn's optimization testbed CometBoards (the optimizer). For the raked wingtip structure of the Boeing 767-400ER airliner, the stochastic optimization process redistributed the strain field and reduced weight by 17 percent over the traditional design.

This work was done by Shantaram S. Pai and Rula Coroneos of Glenn Research Center and Surya N. Patnaik of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18497-1.

Zinc Oxide Nanowire Interphase for Enhanced Lightweight Polymer Fiber Composites

This technique can be used in applications requiring reduced structural mass, such as in aircraft, missiles, rockets, and balloons.

NASA's Jet Propulsion Laboratory, Pasadena, California

The objective of this work was to increase the interfacial strength between aramid fiber and epoxy matrix. This was achieved by functionalizing the aramid fiber followed by growth of a layer of ZnO nanowires on the fiber surface such that when embedded into the polymer, the load transfer and bonding area could be substantially enhanced. The functionalization procedure developed here created functional carboxylic acid surface groups that chemically interact with the ZnO and thus greatly enhance the strength of the interface between the fiber and the ZnO.

The matrix-ZnO interface is enhanced through increased surface area (>1,000 times), mechanical interlocking, and the creation of a functional gradient between the nanowires and matrix, which has been shown to improve the interface strength of a carbon fiber composite by well over 100 percent. The composite compressive strength, shear strength, shear modulus, interlaminar shear strength, and interfacial shear strength should all be enhanced because the graded interface reduces the stress concentration at the discrete fiber-to-matrix boundary.

The first milestone of the project was to develop the functionalization procedure to enhance the attachment of the ZnO nanowires to the aramid fiber. This was achieved with carboxylic acid groups that split the peptide bond, catalyzed by a strong base, and created a carboxylate and a primary amine functional group. Carboxylic acid groups are specifically chosen because they often discharge a proton leading to charge coordination between the negative oxygen atoms and the positive zinc ions. Furthermore, the bond angles of carboxylic acid functional groups are