General Information

Title of Technology Development: Compact Termination for Structural Soft-goods

Responsible NASA Mission Directorate or Office: Center Independent Research & Development

NASA Lead Center or Facility: Johnson Space Center

NASA Supporting Centers and Facilities: No data provided

NASA Program: Center Innovation Fund: JSC CIF (also includes JSC IRAD)

NASA Project: 12420

NASA Program Executive: Minoo Dastoor

NASA Program Manager: Ronald G Clayton

NASA Project Manager: Robert Wilkes

Principal Investigator: Robert Wilkes

States with Work: TX

Contractors Performing Work: Jacobs Technology, Inc.

Sources of Funding

NASA Mission Directorates or Offices Providing Funding/Resources: Center Independent Research & Development, Center Innovation Fund

NASA Centers and Facilities Providing Funding/Resources: Johnson Space Center

Other U.S. Government Agencies Providing Funding/Resources: No data provided

U.S. External Partners Providing Funding, Academia or Commercial: No data provided

International Partners Providing Funding/Resources: No data provided

Technology Project's Mappings

Primary Space Technology Roadmap - Technology Area: TA 7: Human Exploration Destination Systems

– Detailed Primary Space Technology Roadmap - Technology Area: TA 7.4: ?Advanced? Habitat Systems

Secondary Space Technology Roadmap - Technology Area: TA 12: Materials, Structures, Mechanical Systems & Manufacturing

Additional Space Technology Roadmap - Technology Area: TA 6: Human Health, Life Support & Habitation Systems

Project Details

Project Start Date: May-01-2012	**Project End Date:** Aug-01-2012
Project Start TRL: 2	**Project End TRL:** 4

Brief Description (abstract) of Technology Project: Glass fiber is unique in its ability to withstand atomic oxygen and ultraviolet radiation in-space environments. However, glass fiber is also difficult to terminate by traditional methods without decreasing its strength significantly. Glass fiber products are especially sensitive to bend radius, and do not work very well with traditional 'sewn loop on pin' type connections. As with most composites, getting applied loads from a metallic structure into the webbing without stress concentrations is the key to a successful design. A potted end termination has been shown in some preliminary work to out-perform traditional termination methods. It was proposed to conduct a series of tensile tests on structural webbing or cord to determine the optimum potting geometry, and to then be able to estimate a weight and volume savings over traditional sewn-over-a-pin connections. During the course of the investigation into potted end terminations for glass fiber webbing, a new and innovative connection was developed that has lower weight, reduced fabrication time, and superior thermal tolerance over the metallic end terminations that were to be optimized in the original proposal. This end termination essentially transitions the flexible glass fiber webbing into a rigid fiberglass termination, which can be bolted/fastened with traditional methods.

Technical Performance Measures:

Measure	Unit	Quantity

Description of Capability This Technology Provides: An extremely compact, lightweight, and thermally insensitive end termination for glass fiber webbing was developed and tested, sustaining the full rated strength of the webbing in tensile tests. The end termination consists of fiberglass sheet, bonded to the webbing using epoxy or similar structural adhesive. The fiberglass sheet has well-known properties, and can be drilled and finished through conventional methods.

Anticipated Benefit to NASA for Funded Missions: No data provided

Anticipated Benefit to NASA for Unfunded/Planned Missions: Damage-tolerant inflatable habitats - inflatable modules to the ISS, inflatable exploration vehicles, inflatable planetary habitats.

Anticipated Benefit to Commercial Space Industry or Other Government Agencies: Damage-tolerant inflatable habitats - inflatable modules to the ISS (such as what Bigelow is designing) , inflatable exploration vehicles, inflatable planetary habitats.

Detailed Description of Technology Project

Space environments are particularly harsh for the high-strength fibers we have come to rely on for soft structures. Kevlar, Nomex, Nylon, and other synthetic fibers are broken down by exposure to the combination of vacuum, atomic oxygen, and ultraviolet radiation. Glass fiber does not have this same susceptibility, but requires an end termination that does not bend its fibers. Many proposals for future manned space habitation use inflatable soft structures to produce large habitable volumes. Glass fiber is unique in it's ability to withstand atomic oxygen and ultraviolet radiation without degradation, however, it is subject to failure at reduced loads if it is bent over a tight radius. Unfortunately, current practice has been developed with fibers that do not have this shortcoming, and end terminations are typically made by sewing a loop and placing it in a clevis / pin connection. Proof-of-concept work has been performed on potted terminations using a flight-rated high temperature epoxy. This work has produced tensile specimens with close to the breaking strength of the webbing. The initial termination using epoxy potting and aluminum termination blocks was investigated with various lengths of webbing potted, and pulled to failure. Through this testing, it was determined that a 1/2" long bonded length was required to develop full strength in 1" wide webbing, 0.03 thick. While showing promise compared to a pin-and-loop termination, the aluminum termination block has several disadvantages: 1) the end terminations must be both taller and wider than the webbing itself. 2) the potting process employs a cleaning process to which the fiber is sensitive. This was assumed to be needed to get a high-strength bond directly to the glass fiber. Failure was often observed at the edge of the cleaned fiber. 3) the termination block and the fiber/epoxy composite bond will have to be shown to be robust enough to survive vacuum, thermal extremes, and any other environmental conditions to which the structure will be subjected to. During the course of development, some thought was given to the elimination of these disadvantages. Changing the end termination material from aluminum to fiberglass offered improvements in all three areas of concern. The end termination that resulted is no wider than the webbing itself, and shorter than the aluminum version. The compatibility of the webbing bond to the end fitting is clearly superior, as both are glass/epoxy composites, and will be affected similarly by environmental factors. Lastly, changes to both simplify and reduce stress on the glass fibers during cleaning were implemented, demonstrating that full webbing strength can be obtained. The sum of these design iterations resulted in significant improvements in reliability and strength of the joint, with a reduction size and weight. The resulting end termination is one fifth to one tenth the weight of conventionally terminated webbing, and is volumetrically smaller by about the same ratio. Attachment to other structural elements may be through a pinned or bolted arrangement, as was used in the testing, or in the case of a composite structure (carbon/epoxy or glass fiber/epoxy), this new end termination can be bonded directly to the composite structure.