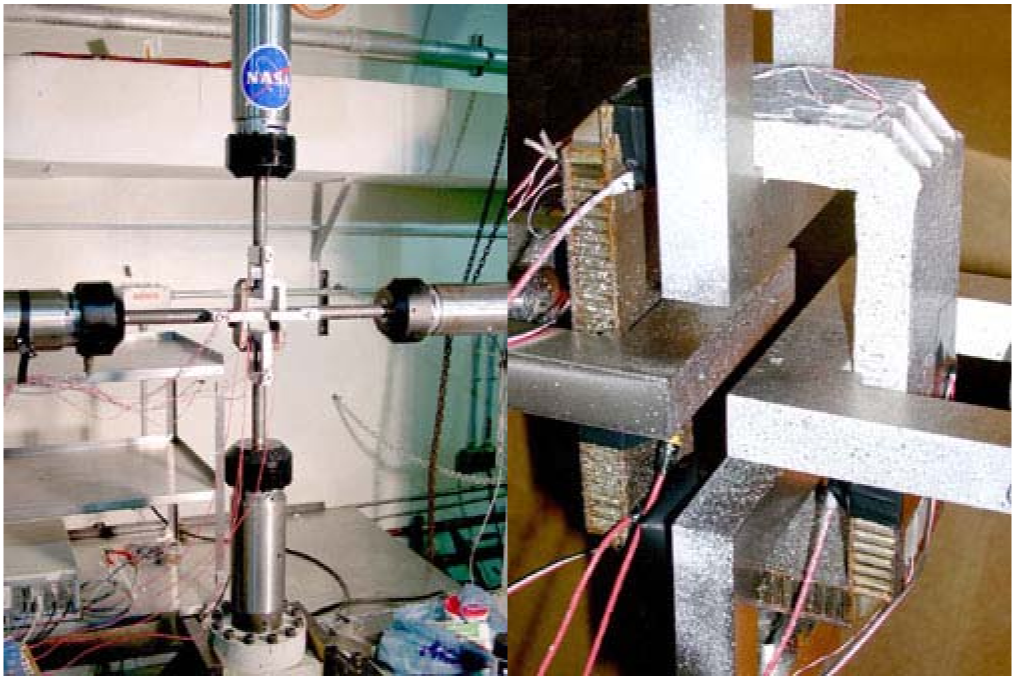
Structural Benchmark Tests of Composite Combustion Chamber Support Completed



Left: Benchmark test configuration for simulated pressure loading of a combustion-chamber support test article. Right: Test-article honeycomb core with face sheets (speckle pattern applied for photographic strain correlation).

Long description of figures 1 and 2. Left: Test article mounted in a large in-plane biaxial test frame. Perpendicular fixtures radiate from the specimen to the frame's hydraulic actuators. Right: Closeup of a rectangular test specimen, approximately 3 by 5 inches in cross section and 2 inches through the thickness. Strain gauges and acoustic emission sensors are visible, as are rollers, which apply line loads to the inside faces of the four sides.

A series of mechanical load tests was completed on several novel design concepts for extremely lightweight combustion chamber support structures at the NASA Glenn Research Center (http://www.nasa.gov/glenn/). The tests included compliance evaluation, preliminary proof loadings, high-strain cyclic testing, and finally residual strength testing of each design (see the photograph on the left). Loads were applied with single rollers (see the photograph on the right) or pressure plates (not shown) located midspan on each side to minimize the influence of contact stresses on corner deformation measurements. Where rollers alone were used, a more severe structural loading was produced than the corresponding equal-force pressure loading: the maximum transverse shear force existed over the entire length of each side, and the corner bending moments were greater than for a distributed (pressure) loading. Failure modes initiating at the corner only provided a qualitative indication of the performance limitations since the stress state was not identical to internal pressure. Configurations were tested at both room and elevated temperatures. Experimental results were used to evaluate analytical prediction tools and finite-element methodologies for future work, and they were essential to provide insight into the deformation at the corners. The tests also were used to assess fabrication and bonding details for the complicated structures. They will be used to further optimize the design of the support structures for weight performance and the efficacy of corner reinforcement.

The test articles were fabricated using sandwich construction technology to provide high specific structural efficiency (refs. 1 to 4). Inner stainless steel face sheets supported a flexible, rectangular, thin-walled, cooled combustion chamber (chamber not included in the benchmark test pieces), and a titanium foil honeycomb core tied this to the outer polyimide-carbon-fiber polymer-matrix-composite face sheets. Some designs included exterior polymer-matrix-composite reinforcements across the four corners. All components were bonded together with high-temperature adhesive and were cured at the design operating temperature. The chamber support designs were developed for use in a hypersonic air-breathing rocket-based combined-cycle propulsion system. The rectangular cross section was a function of the combustion process as well as the vehicle-engine aerodynamics. The composite combustion chamber support was a collaborative effort between NASA and Rocketdyne Propulsion & Power of the Boeing Company (http://www.boeing.com/space/rdyne/flash.html).

These ongoing tests were conducted at Glenn's Structural Benchmark Test Facility by the Polymers Branch (http://www.grc.nasa.gov/WWW/MDWeb/5150/Polymers.html) in collaboration with the Life Prediction Branch (http://www.grc.nasa.gov/WWW/LPB/). They used a large 500-kN (110,000-lb)-capacity in-plane biaxial load frame to simulate pressure loading through four hydraulic actuators applying scaled loads to the test articles' inner surfaces. The load frame included a fully digital data acquisition and control system. A hot-air furnace provided uniform specimen temperatures for the isothermal elevated-temperature tests. A four-sensor acoustic emissions system monitored crack initiation, adhesive debonds, and other anomalies. Real-time strains were measured with eight strain gauges, and full-field two- and three-dimensional surface strain plots were produced post test through correlation with high-resolution digital images of random speckle patterns applied to the specimens. Digital-format video recordings were made of the residual strength tests. Elevated- and room-temperature tests of alternative designs are expected to be completed in fiscal year 2005.

References

1. Shin, E. Eugene, et al.: Design and Fabrication Issues of High Temperature PMCs for Aerospace Propulsion Applications. Presented at SAMPE 2002, Long Beach, CA, May 2002.
2. Stokes, Eric H.; Shin, E. Eugene; and Sutter, James K.: Mechanical Testing of PMCs Under Simulated Rapid Heat-Up Propulsion Environments. Presented at SAMPE 2002, Long Beach, CA, May 2002.

3. Thesken, J.C., et al.: Thermomechanical Fatigue of Polyimide Composites in Reusable Propulsion Systems. Presented at SAMPE 2004, Long Beach, CA, May 2004.
4. Thesken, J.C., et al.: Design Analysis of a Composite Combustion Chamber Support. Presented at SAMPE 2004 (http://www.sampe.org), Long Beach, CA, May 2004.

Find out more about this research:
NASA Glenn Research Center at http://www.nasa.gov/centers/glenn/home/index.html
Polymers Branch at http://www.grc.nasa.gov/WWW/MDWeb/5150/Polymers.html
Life Prediction Branch at http://www.grc.nasa.gov/WWW/LPB/
Boeing-Rocketdyne at http://www.pratt-whitney.com/prod_space.asp

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