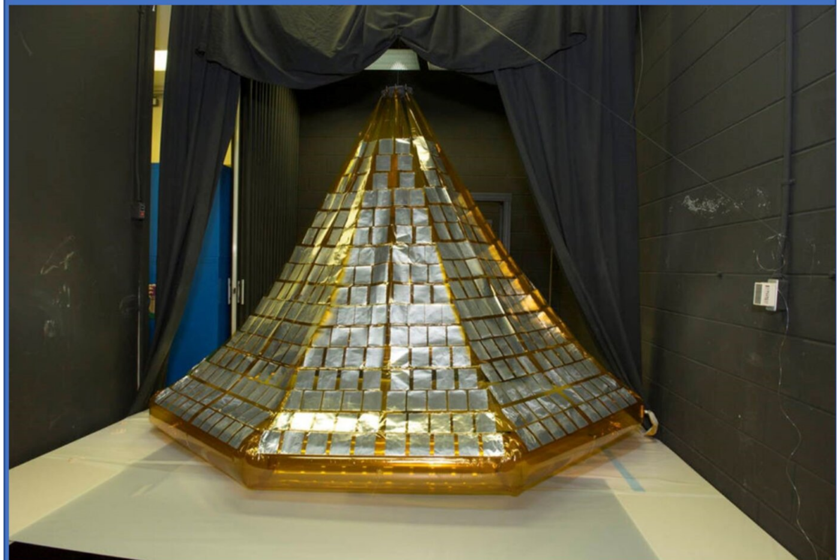


National Aeronautics and
Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

Low Creep, Low Relaxation Fiber-Reinforced Polymer Composites

Increased dimensional stability

Inflatable and deployable beams and masts such as solar sail supports used in space missions are often made of polymer composites and may be stored for one to two years in space before deployment. While stored, these polymer composites degrade on a molecular level, which can limit the ability of the beams to unfurl properly, reducing performance or even failing to unfurl. Researchers at NASA’s Langley Research Center developed a fiber-reinforced polymer composite to reduce the effect of viscoelastic creep and prolong the molecular integrity of polymer-based beams over time. NASA’s polymer composite technology augments the molecular structure of the resin matrix by incorporating secondary additives and adjusting the composite architecture. Test results show that the new material reduces relaxation in the modified-molecular structure –to as low as 5% from the initial modulus after two years. This compares to 49% relaxation after one year for the state-of-the-art, commercially available options.

BENEFITS

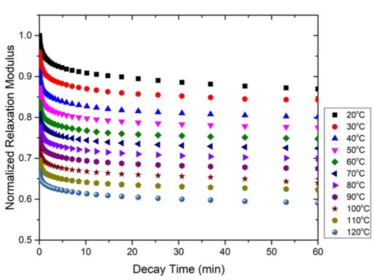
- Improved Dimensional Stability: suppresses the onset of viscoelastic creep and relaxation
- Enhanced Properties: heightened specific strength and specific stiffness
- Variety: new polymeric materials and fiber-reinforced polymer composites
- Easy to Make: uses commercially available materials

THE TECHNOLOGY

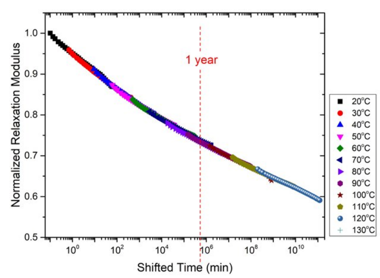
NASA used three strategies to develop a family of modified epoxy resins for use in an improved composite layup configuration. By tailoring molecular structures, incorporating secondary additives, and adjusting composite architecture, NASA has produced fiber-reinforced polymer composites that suppress viscoelastic creep and relaxation. Specifically the three strategies were:

(1) Controlling the cross-linking density using reactive functional groups and selecting appropriate monomers with stoichiometry adjustments. A higher stoichiometric ratio is responsible for reduced relaxation compared to a lower ratio (resulting in 26% relaxation after 1 year vs. 49%).
(2) Increase the steric hindrance by reducing free volume and enhancing intermolecular interaction. This involved the preparation of two different reactive low molecular weight oligomers The best epoxy resin created was from the VCD/HAA additives with 15-17% relaxation; DEGBA/HAA had 22-25% relaxation.
(3) Optimizing different carbon fiber layup configurations for woven structures made into a highly stiff boom, highly flexible boom, a small size boom, and a large size boom application. The best configuration was that of a highly stiff boom with 4-5% relaxation. Other carbon fiber layup configurations had 16-30% relaxation.

As shown in the figure below, NASA tested the relaxed composite using an accelerated test with variable temperatures.



Stress relaxation data of a tetrafunctional epoxy sample at different temperatures



A master curve of relaxation modulus created by the time-temperature-superposition method

APPLICATIONS

The technology has several potential applications:

- Aerospace: durable and stable inflatable and deployable structures (e.g., payload booms, solar sail deployable booms, solar power arrays, antenna supports, space habitats, planetary decelerators)
- Military: reinforced body armor for soldiers (e.g., vest, combat helmet, gloves), inflatable and deployable structures (e.g., barracks), reinforced shock-absorbing material for vehicles and aircraft, material for advanced combat weapons and tools
- Wind Energy: turbines
- Marine: hull boats in structural frames, keels, masts, poles, boom, winch drums, and shafting
- Sporting goods: improved durability and mechanical stability of a wide variety of sporting goods such as snow boards, golf clubs, tennis racquets, hockey sticks, etc.

PUBLICATIONS

Patent Pending

More Information

National Aeronautics and Space Administration

Agency Licensing Concierge

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