Materials & Coatings

Multi-scale CNT-Based Reinforcing Polymer Matrix Composites for Lightweight Structures

Applications include commercial aircraft, sports equipment, and automobiles.

Marshall Space Flight Center, Alabama

Reinforcing critical areas in carbon polymer matrix composites (PMCs), also known as fiber reinforced composites (FRCs), is advantageous for structural durability. Since carbon nanotubes (CNTs) have extremely high tensile strength, they can be used as a functional additive to enhance the mechanical properties of FRCs. However, CNTs are not readily dispersible in the polymer matrix, which leads to lower than theoretically predicted improvement in mechanical, thermal, and electrical properties of CNT composites. The inability to align CNTs in a polymer matrix is also a known issue. The feasibility of incorporating aligned CNTs into an FRC was demonstrated using a novel, yet commercially viable nanofiber approach, termed NRMs (nanofiber-reinforcing mats). The NRM concept of reinforcement allows for a convenient and safe means of incorporating CNTs into FRC structural components specifically where they are needed during the fabrication process.

NRMs, fabricated through a novel and scalable process, were incorporated into FRC test panels using layup and vacuum bagging techniques, where alternating layers of the NRM and carbon prepreg were used to form the reinforced FRC structure. Control FRC test panel coupons were also fabricated in the same manner, but comprised of only carbon prepreg. The FRC coupons were machined to size and tested for flexural, tensile, and compression properties. This effort demonstrated that FRC structures can be fabricated using the NRM concept, with an increased average load at break during flexural testing versus that of the control.

The NASA applications for the developed technologies are for lightweight structures for in-space and launch vehicles. In addition, the developed technologies would find use in NASA aerospace applications such as rockets, aircraft, aircraft/spacecraft propulsion systems, and supporting facilities. The reinforcing aspect of the technology will allow for more efficient joining of fiber composite parts, thus offering additional weight savings. More robust structures capable of withstanding micrometeoroid and space debris impacts will be possible with the enhanced mechanical properties imparted by the aligned CNTs incorporated into the fiber composite structure, as well as the potential for improved electrical and thermal properties.

The materials fabrication approach developed in the present effort is a platform for customer applications where additional reinforcement is required or would be beneficial, especially in FRC structures and component parts. Depending upon the specific customer application, the NRM could be tailored to the specific matrix resin and desired property enhancement.

This work was done by Daniel Eberly, Runqing Ou, Adam Karcz, and Ganesh Skandan of NEI Corporation, and Prof. Patrick Mather and Erika Rodriguez of Syracuse University for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32998-1.

Ceramic Adhesive and Methods for On-Orbit Repair of Re-Entry Vehicles

Material can be applied in space to repair damage that requires heat/oxidation protection upon re-entry to Earth's atmosphere.

Lyndon B. Johnson Space Center, Houston, Texas

This adhesive is capable of repairing damaged leading edge components of re-entry vehicles while in space, and is novel with regard to its ability to be applied in the vacuum of space, and in a microgravity environment. Once applied, the adhesive provides thermal and oxidation protection to the substrate (in this case, reinforced carbon/carbon composites, RCCs) during re-entry of a space vehicle. Although there may be many formulations for repair adhesives, at the time of this reporting, this is the first known adhesive capable of an on-orbit repair.

The adhesive is an engineered ceramic material composed of a pre-ceramic polymer and refractory powders in the form of a paste or putty that can be applied to a scratched, cracked, or fractured composite surface, covering and protecting the damaged area. The adhesive is then "cured" with a heat cycle, thereby cross-linking the polymer into a hardened material and bonding it to the substrate. During the heat of re-entry, the material is converted to a ceramic coating that provides thermal and oxidative stability to the repaired area, thus allowing the vehicle to pass safely from space into the upper atmosphere.

Ceramic powders such as SiC, ZrB_2 and Y_2O_3 are combined with allylhydridopolycarbosilane (AHPCS) resin, and are mixed to form a paste adhesive. The material is then applied to the damaged area by brush, spatula, trowel, or other