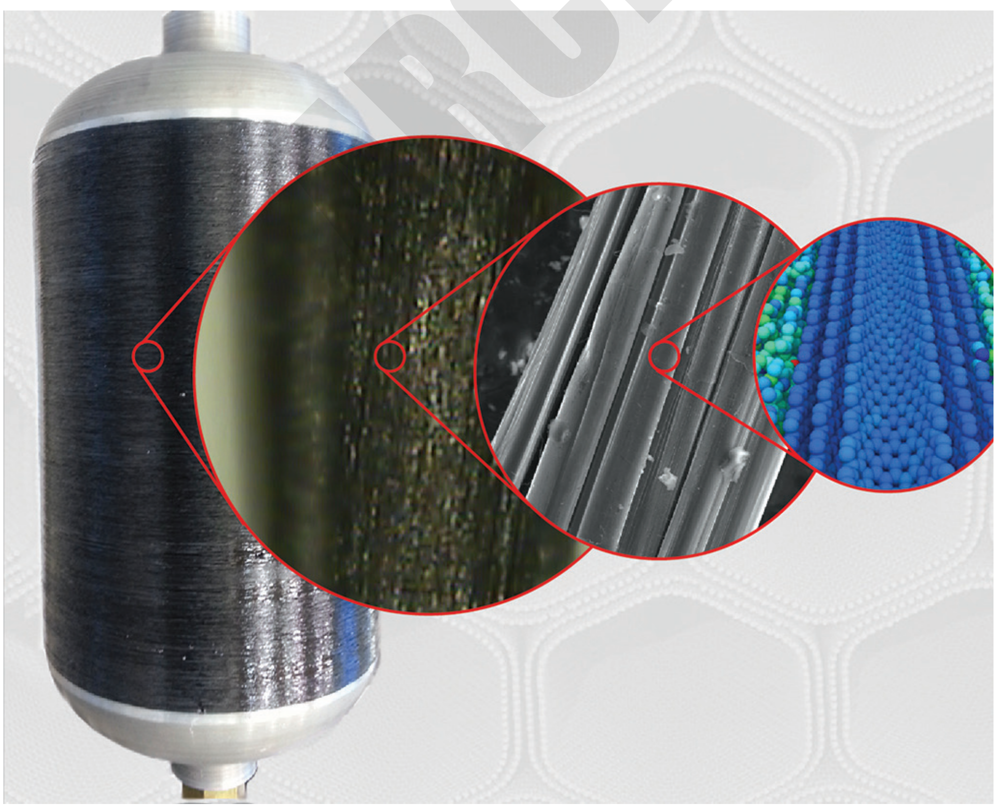
Space Technology

Game Changing Development

Carbon Nanotube (CNT) Composite Winding Process

Revolutionary design concepts in future aerospace vehicles will depend on extraordinary material properties to permit significant reduction in mass and size of components, while imparting intelligence. Due to their combination of remarkable electrical and mechanical properties, CNTs have the potential to enable this paradigm shift in design concepts. However, significant challenges still exist in translating these CNT properties into the macrostructures required for future generations of aerospace vehicles. Among the challenges are large-scale production of CNTs that possess the high strength mechanical properties of the nanoscale constituents, in formats that are suitable for manufacturing structural components, and the development of CNT processing methods to take advantage of these mechanical properties.

The novel properties of CNTs make them a promising candidate for a variety of applications. However, the potential of CNTs can only be fully exploited if these excellent nanoscale properties can be retained in macroscale articles. A team of researchers from NASA's



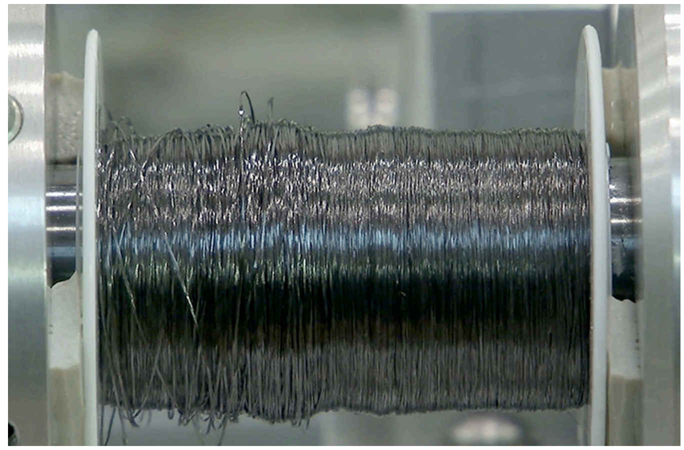
Demonstration flight article wrapped with carbon nanotube composite. Zoom shows carbon nanotubes used and simulation developed to support process development.

Langley Research Center (LaRC), Glenn Research Center (GRC), and Marshall Space Flight Center (MFRC), industry, and academia have been advancing the development of high strength Carbon Nanotube (CNT) yarns for structural applications. Development activities spanned the enhancement of tensile properties of CNT yarns in collaboration with the CNT manufacturer, and investigation of approaches to make high strength composites suitable for use in composite overwrapped pressure vessels. The CNT processing methods, including CNT yarn infiltration and CNT composite winding, were developed by winding a series of subscale test rings, and successfully demonstrated through the creation of a research scale CNT composite overwrapped pressure vessel at MSFC.

The CNT composite winding process was developed through the Nanotechnology project, which is led by GRC and supported by funding from the Game Changing Development (GCD) Program, which is a part of NASA's Space Technology Mission Directorate. The CNT composite winding process developed at LaRC, GRC, and MSFC is a streamlined, simple processing method that has yielded consistent results. In realizing these achievements, the team was challenged to advance the process from research scale to the commercial scale within a few months.

The CNT composite overwrap development team has transferred the process to MSFC for adaptation to a commercial winder. Transferring the process raises the CNT manufacturing maturation level, because it moves the technology from the laboratory to infrastructure used to manufacture larger articles that are integrated into aerospace applications. NASA's flight article manufacturing is performed at MSFC, and this emerging high-strength material technology is under continuing development, moving toward flight testing on a small scale CNT composite overwrapped pressure vessel.

The capability at MSFC is in the fabrication of carbon fiber composite, and CNT yarns do not have the same characteristics as carbon fibers. Among the challenges in process scale-up is making modifications to existing commercial equipment so that it can handle carbon nanotube yarns. Some of the components of the MSFC commercial carbon fiber composite machine have been modified to accommodate the characteristics of CNT yarns.



Spool of carbon nanotube yarn.

Individual carbon nanotubes are 1000 times stronger and about 50 times stiffer than aluminum (Al). They are more than 10 times stronger and about five times stiffer than IM7 carbon fiber. Their current-carrying capacity can exceed copper (Cu), and the thermal conductivity is about 20 times better than Al and nine times better than Cu. The nanotubes are almost half the density of Al and about 15% that of Cu.

The CNT composites currently being manufactured and tested are far from optimum. However, these composites are displaying tensile properties comparable to conventional carbon fiber composites. The current testing and evaluation suggest that there is a lot of untapped potential in CNT composite structures. Further development of the CNT composite technology will lead to significant improvements in mechanical properties. The broad impact for the field of nanotechnology is that this testing constitutes a first step toward demonstrating the attractive mechanical properties of CNTs for large space flight structures.

The GCD Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space.

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http://gameon.nasa.gov/

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