Lightweight, Ultra-High-Temperature, CMC-Lined Carbon/Carbon Structures

This refractory composite material is applicable to defense vehicles, combustion chambers, rocket nozzles, hot gas generators, and valves using both liquid and solid propellants.

John H. Glenn Research Center, Cleveland, Ohio

Carbon/carbon (C/C) is an established engineering material used extensively in aerospace. The beneficial properties of C/C include high strength, low density, and toughness. Its shortcoming is its limited usability at temperatures higher than the oxidation temperature of carbon — approximately 400 °C. Ceramic matrix composites (CMCs) are used in place of C/C to a bulk structure of C/C retains all of the benefits of C/C with the high temperature oxidizing environment usability of CMCs.

Ultramat demonstrated the feasibility of combining the light weight of C/C composites with the oxidation resistance of zirconium carbide (ZrC) and zirconium-silicon carbide (Zr-Si-C) CMCs in a unique system composed of a C/C primary structure with an integral CMC liner with temperature capability up to 4,200 °F (≈2,315 °C). The system effectively bridged the gap in weight and performance between coated C/C and bulk CMCs. Fabrication was demonstrated through an innovative variant of Ultramat's rapid, pressureless melt infiltration processing technology. The fully developed material system has strength that is comparable with that of C/C, lower density than Cf/SiC, and ultra-high-temperature oxidation stability. Application of the reinforced ceramic casing to a predominantly C/C structure creates a highly innovative material with the potential to achieve the long-sought goal of combining the light weight of C/C combined with the high temperature oxidizing environment usability of CMCs.

The melt-infiltrated CMC-lined C/C composites offered a lower density than Cf/SiC. The melt-infiltrated composites offer greater use temperature than Cf/SiC because of the more refractory ceramic matrices and the C/C substructure provides greater high-temperature strength.

This work was done by Matthew J. Wright, Laura Evans, and Jennifer C. Xu of Glenn Research Center; Randy L. Vander Wal of Pennsylvania State University; and Gordon M. Berger and Michael J. Kulis of the National Center for Space Exploration Research. Further information is contained in a TSP (see page 1). Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18618-1.