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MEMORANDUM FOR PRS (In-House Publication)

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FROM: PROI (STINFO)

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2001-217**
Wesley Hoffman (PRSM), "In Situ Processing Route for Uniform Density Carbon-Carbon Composites"

(Statement A)

Journal:
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In Situ Processing Route For Uniform Density Carbon-Carbon Composites

A recent development in composite processing at the Air Force Research Laboratory (AFRL) in Edwards CA drastically reduces both the cost of and processing time required for high performance carbon-carbon (C-C) composites. These composites possess a unique set of properties that make them ideal materials for high temperature structural uses, such as in rocket propulsion components, hypersonic vehicles, and aircraft brakes. C-C composites are stronger and stiffer than steel, while less dense than aluminum. In addition, they not only maintain their mechanical properties to temperatures in excess of 3000° C, the composite's material properties actually improve with heating as the non-ordered carbon is converted to the ordered graphite structure through the process of graphitization. In spite of their excellent properties, the use of carbon-carbon composites has been limited because of their high cost and oxidation at elevated temperatures.

For about thirty years, carbon-carbon composites have been manufactured principally by two processes, which differ in the means used to place the matrix between the fibers and thus "densify" the composite. One process involves infiltrating the composite preform with a hydrocarbon gas, while the other involves impregnating the fiber preform with a liquid hydrocarbon such as a pitch or resin. Both of these processes are followed by carbonization, which removes all non-carbon atoms and then by the graphitization process in which the partially densified composite is heated to temperatures in excess of 2400° C in order to enhance mechanical properties.

After the composite is graphitized, both current processes require that the outside of the partially densified composite be machined to remove material. This is necessary because both processes preferentially densify the outside of the composite and block the surface pores so that additional densification cannot occur. Because of this shortcoming, the infiltration/impregnation-carbonization-graphitization-machining cycle must be repeated a minimum of 3 times. Since each cycle requires 3-4 weeks, the densification process is very long and costly. By understanding the reasons for the shortcomings of current commercial processing, the In-Situ Rapid Densification Process, developed at the AFRL Propulsion Directorate, is able to avoid inhomogeneous densification and reduce the time required from many months to less than two weeks, with an associated dramatic decrease in cost.

AFRL's In-Situ Densification Process is an impregnation process that, in contrast to commercial processes, is able to rapidly densify the composite uniformly because it addresses the conflicting requirements of the impregnant's low viscosity and good wettability on the one hand and the need for a high char yield carbon precursor on the other. This is accomplished by using a low viscosity impregnant that wets the fiber preform surface in the first step of the process. This impregnant is sucked into the fiber preform like water into a sponge. This not only results in a uniform density, but, in addition, there is also no need for machining after densification to open up the surface pores. After the impregnant has filled the preform, in the second step of the process it is polymerized into a carbon matrix precursor that has a high carbon yield which means that fewer cycles are needed to bring the composite to final density. The carbon matrix precursor is then pyrolyzed to produce a high quality carbon matrix.

Not only does the In Situ Process produce a uniformly densified composite from any type of fiber preform (woven, braided, 1-D to n-D, felt, etc.) but, in contrast to other processes, there does not appear to be a size limitation. That is, preforms with diameters up to 45 cm in diameter and lengths to 183 cm have been uniformly densified. In addition, another unique feature of this technology is

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the ability to join carbon-carbon parts together with a seamless joint that possess significant mechanical strength.

Finally, it should be noted that, in contrast to other processes, it is not necessary to graphitize the composites which results in significant time and energy savings. Even without graphitization, the ablation and erosion performance of the In-Situ material equals that of commercial material when exposed to the exhaust of either liquid rocket engines or solid rocket motors. Thus, in most applications, it is not necessary to graphitize the material. However, when this material is exposed to graphitization temperatures in excess of 2200° C, a highly graphitic material with high thermal conductivity results. The significance of this result is that it is possible to use the low-cost liquid phase process to produce a C-C composite with the properties of a composite produced employing a gas-phase process. It is anticipated that the dramatic decrease in processing cost associated with this process will allow many new applications for this material to become a reality.

Opportunities:

The High Temperature Components Group welcomes inquiries from those interested in Cooperative Research and Development to utilize this process in the fabrication of their technology.

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