

Abstract for the International Symposium on Airbreathing Engines (17th ISABE), Contributed Technical Paper Session, Materials & Structures

ADVANCED CONSTITUENTS AND PROCESSES FOR CERAMIC COMPOSITE ENGINE COMPONENTS

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The successful replacement of metal alloys by ceramic matrix composites (CMC) in hot-section engine components will depend strongly on optimizing the processes and properties of the CMC microstructural constituents so that they can synergistically provide the total CMC system with improved temperature capability and with the key properties required by the components for long-term structural service. This presentation provides the results of recent activities at NASA aimed at developing advanced silicon carbide (SiC) fiber-reinforced hybrid SiC matrix composite systems that can operate under mechanical loading and oxidizing conditions for hundreds of hours at 2400 and 2600°F, temperatures well above current metal capability. These SiC/SiC composite systems are lightweight (~30% metal density) and, in comparison to monolithic ceramics and carbon fiber-reinforced ceramic composites, are able to reliably retain their structural properties for long times under aggressive engine environments.

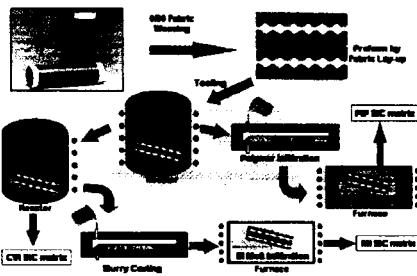
It is shown that the improved temperature capability of the SiC/SiC systems is related first to the NASA development of the Sylramic-iBN SiC fiber, which displays high thermal stability, creep resistance, rupture resistance, and thermal conductivity, and possesses an in-situ grown BN surface layer for added environmental durability. This fiber is simply derived from Sylramic SiC fiber type that is currently produced at ATK COI Ceramics. Further capability is then derived by using chemical vapor infiltration (CVI) to form the initial portion of the hybrid SiC matrix. Because of its high creep resistance and thermal conductivity, the CVI SiC matrix is a required base constituent for all the high temperature SiC/SiC systems. By subsequently thermo-mechanical-treating the CMC preform, which consists of the Sylramic-iBN fibers and CVI SiC matrix, process-related defects in the matrix are removed, further improving matrix and CMC creep resistance and conductivity.

For the 2400°F SiC/SiC system, remaining porosity in the CMC preform is then filled by the high-temperature melt infiltration (MI) of silicon alloys, resulting in a SiC/SiC system with very low porosity and high thermal conductivity, a major property requirement for engine components that will experience high thermal gradients during service. However, to achieve long-term structural service above 2400°F, complete elimination of silicon in the matrix is required, so that alternate approaches for minimization of porosity in the CMC preform are needed. One such approach, which is currently being used for the 2600°F SiC/SiC system, is that of polymer infiltration and pyrolysis (PIP), as shown in Fig. 1-left. For this process, a liquid SiC-yielding polymer

is infiltrated at room temperature into the porosity of the CMC preform, and then the entire system is heated to a high temperature to convert the polymer to a high conductivity CMC material. Because of weight loss during polymer conversion, some matrix porosity in the final system still remains. Nevertheless, this porosity has been shown to not be detrimental to structural performance, but needs to be further reduced for maximizing system thermal conductivity.

Based on a list of first-order property goals for typical engine components, data from a variety of laboratory tests on simple two-dimensional panels (see Fig. 1-right) are presented that demonstrate that the 2400 and 2600°F SiC/SiC systems with CVI + MI and CVI + PIP hybrid matrices, respectively, have the desired thermal and structural capabilities. Remaining microstructural issues for further property enhancement are discussed, as well as on-going approaches at NASA to solve these issues. In addition, to aid in implementation of these advanced materials into engine hot-section components, progress is briefly discussed concerning NASA efforts to develop design data-bases for the SiC/SiC systems as well as property and life models that are able to take into account the effects of different component architectures and service conditions.

Typical Processes for SiC/SiC CMC



SiC/SiC CMC SHORT-TERM PROPERTIES
(EFFECT OF FIBER & MATRIX TYPES)
(tested in air - 5,000 Pa/sec. tension)

