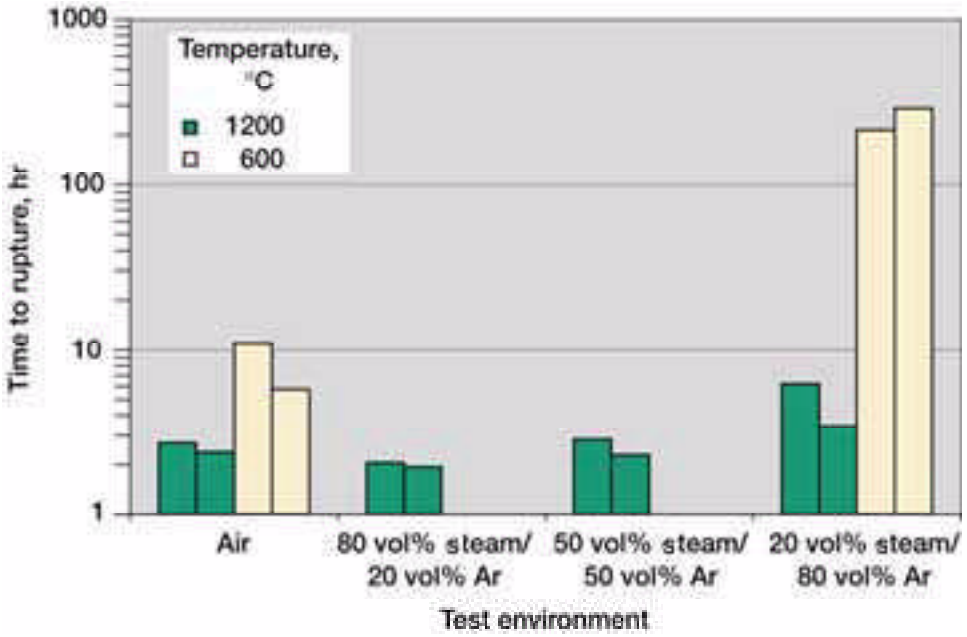
Effect of Environment on the Stress-Rupture Behavior of a C/SiC Composite Studied

Advanced reusable launch vehicles will likely incorporate fiber-reinforced ceramic matrix composites (CMC's) in critical propulsion and airframe components. The use of CMC's is highly desirable to save weight, improve reuse capability, and increase performance. One of the candidate CMC materials is carbon-fiber-reinforced silicon carbide (C/SiC).

In potential propulsion applications, such as turbopump rotors and nozzle exit ramps, C/SiC components will be subjected to a service cycle that includes mechanical loading under complex, high-pressure environments containing hydrogen, oxygen, and steam. Degradation of both the C fibers and the SiC matrix are possible in these environments. The objective of this effort was to evaluate the mechanical behavior of C/SiC in various environments relevant to reusable launch vehicle applications. Stress-rupture testing was conducted at the NASA Glenn Research Center on C/SiC specimens in air and steam-containing environments. Also, the oxidation kinetics of the carbon fibers that reinforce the composite were monitored by thermogravimetric analysis in the same environments and temperatures used for the stress-rupture tests of the C/SiC composite specimens.

The stress-rupture lives obtained for C/SiC tested in air and in steam/argon mixtures are shown in the following bar chart. As is typical for most materials, lives obtained at the lower temperature (600 °C) are longer than for the higher temperature (1200 °C). The effect of environment was most pronounced at the lower temperature, where the average test duration in steam at 600 °C was at least 30 times longer than the lives obtained in air. The 1200 °C data revealed little difference between the lives of specimens tested in air and steam at atmospheric pressure.



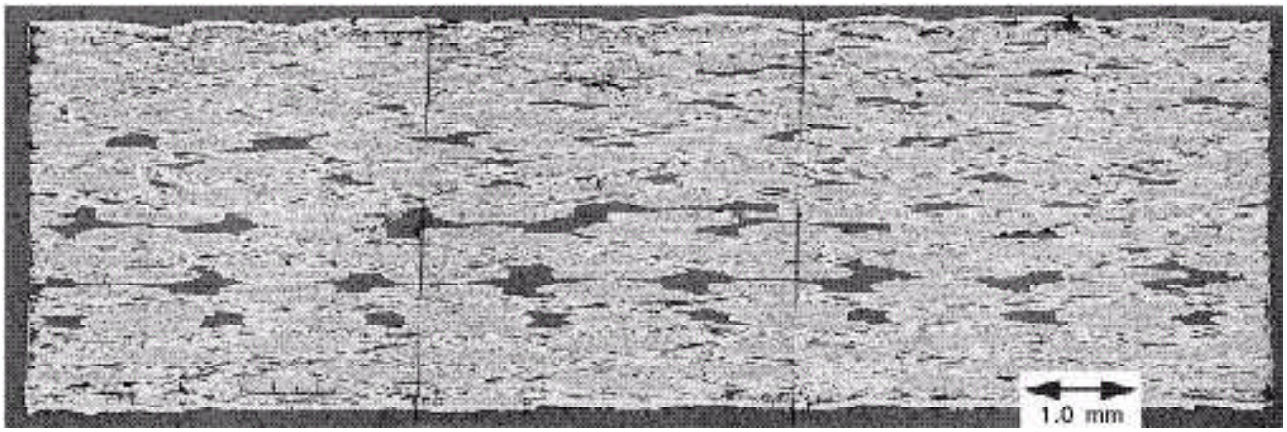
Stress-rupture data for C/SiC revealed that lives vary with test temperature and environment (stress was 10 ksi for all tests).

Long description

Plot of test environment and temperature versus stress-rupture life for C/SiC specimens tested using a composite stress of 10 ksi. The test environments are air, 80% steam/20% argon, 50% steam/50% argon, and 20% steam/80% argon. Lives obtained at 1200 °C in steam environments and in air are all about 3 hr. The specimen life in air at 600 °C is 8.5 hr, whereas in steam the average life is 250 hr.

The damage that occurred during the stress-rupture testing at 600 and 1200 °C in steam is shown in the following photomicrographs. Little composite damage can be seen in the specimen tested at 600 °C, whereas damage, in the form of carbon fiber oxidation, was present in the specimen tested at 1200 °C. Similar damage was found in specimens tested in air. The results revealed that the oxidation rate of the carbon fibers in the various environments correlated with the composite stress-rupture lives.

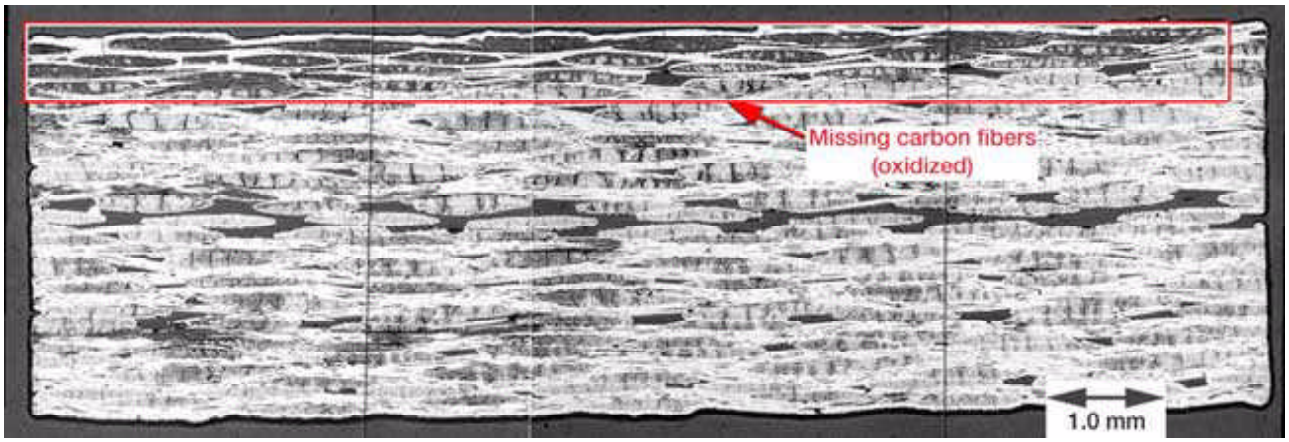
Rupture testing and strength measurement studies are ongoing to guide composite life prediction method development for C/SiC as well as to provide fundamental understanding of the damage mechanisms in ceramic matrix composites in environments relevant to future launch vehicle applications.



Little damage is seen in C/SiC tested in steam at 600 °C for 213 hr.

Long description

Examination of polished cross sections of a C/SiC specimen tested in steam/argon at 600 °C revealed little damage after 214 hr of testing.



C/SiC specimen failure occurred after 2 hr in steam at 1200 °C because of carbon fiber oxidation.

Long description

Examination of polished cross sections of a C/SiC specimen tested in steam/argon at 1200 °C revealed significant damage in the form of carbon fiber oxidation. The specimen failed after 2 hr of testing.

Find out more about this research (http://www.grc.nasa.gov/WWW/EDB/).

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