**Ceramic Matrix Composites (CMCs)**
For
**Gas Turbine Applications**

Krishan L Luthra
GE Corporate Research & Development
Schenectady, NY 12301

The development of high temperature materials over the past forty years has been one of the key factors responsible for improvements in performance of gas turbines. The materials being used today are nickel and cobalt base alloys, which in many cases are being used at temperatures up to ~1100$^o$C, within 50$^o$C of their melting temperature. Consequently, there is a strong need to develop materials that can be used at temperatures higher than ~1100$^o$C.

Ceramics are refractory materials and, thus, attractive for gas turbine applications. Monolithic ceramics, such as SiC and $Si_3N_4$, have been around for over 40 years but have not found applications in gas turbines because they do not have adequate damage tolerance and fail catastrophically. Ceramic Matrix Composites, particularly those reinforced with continuous fibers, alleviate the damage tolerance and are thus attractive for gas turbine applications.

Two classes of CMCs are attractive for high temperature structural applications: oxide fiber oxide matrix composites, so called oxide/oxide composites, and silicon carbide fiber reinforced silicon carbide matrix composites, so called SiC/SiC composites. Oxide/oxide composites are limited to a temperature of ~1100$^o$C because of lack of availability of higher temperature oxide fibers. Moreover, because of their low thermal conductivity and high thermal expansion coefficient, oxide-oxide composites have poor thermal shock resistance, a key requirement for demanding applications in hot sections of gas turbines. Conversely, SiC/SiC composites are attractive for high temperature applications because of availability of high temperature fibers and better thermal shock resistance of SiC.

For over 10 years, GE has been pursuing the development of melt infiltrated SiC/SiC composites. These composites are made by melt infiltration of silicon into a preform containing BN-coated silicon carbide fibers embedded in a matrix of SiC and/or carbon. On infiltration, silicon reacts with carbon to form silicon carbide, and the remaining pores are filled with silicon resulting in a composite with a silicon-silicon carbide matrix with BN-coated silicon carbide fibers. The BN fiber coating provides the damage tolerance to the composite.

Melt infiltrated (MI) SiC/SiC composites are particularly attractive for gas turbine applications because of their high thermal conductivity, excellent thermal shock resistance, creep resistance, and oxidation resistance compared to other CMCs. This talk will briefly cover properties of such composites.

The development of melt infiltrated composites for gas turbines has followed a stepwise approach, starting from material development through laboratory testing to component rig testing under turbine operating conditions, and finally to engine testing of components. Over 1000 hours of successful engine testing has been performed for two shroud components of a 2 MW gas turbine. The talk will briefly cover the results of rig and engine testing.

Although substantial progress has been made, significant risks and challenges still remain before these composites can be commercialized for gas turbine components. These risks will also be discussed.

---

This work was partly funded by DOE under Contract No. DE-FC02-92CE410000 with Joe Mavec as the contract monitor.