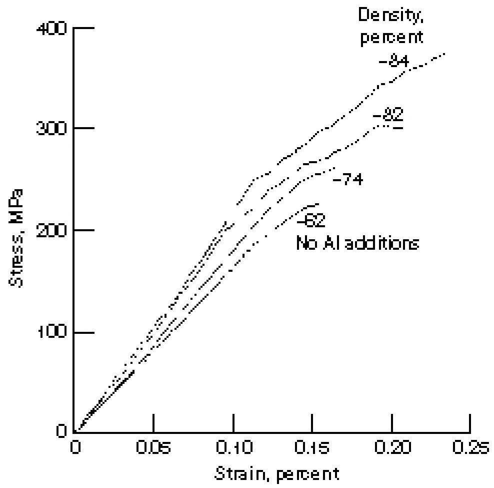
Alternative Processing Method Leads to Stronger Sapphire-Reinforced Alumina Composites

The development of advanced engines for aerospace applications depends on the availability of strong, tough materials that can withstand increasingly higher temperatures under oxidizing conditions. The need for such materials led to the study of an oxide-based composite composed of an alumina matrix reinforced with zirconia-coated sapphire fibers. Because the nonbrittle behavior of this system depends on the interface and its ability to prevent fiber-to-matrix bonding and reduce interfacial shear stress, the microstructure of the zirconia must be carefully controlled during both coating application and composite processing. When it was both porous and unstabilized, zirconia (which does not react easily with alumina) was found to be the most effective material tested in reducing interfacial shear strength between the fiber and matrix.

From initial composite fabrication efforts, processing parameters to maintain the porosity of the interfacial coatings were determined at the NASA Lewis Research Center. Low temperatures and pressures were needed to avoid severe densification of the interfacial coating. Under these conditions, however, densification of the matrix was also limited. It was therefore necessary to alter the composite processing method to increase matrix densification while maintaining the porosity of the fiber coating.



Influence of increased matrix density on composite behavior.

By adding aluminum metal to the matrix and utilizing the conversion of aluminum to aluminum oxide in the initial processing stage of composite formation, it was possible to increase matrix density while maintaining a weak fiber/matrix interface in a sapphire-reinforced alumina matrix composite. The reaction formation of alumina led to an extremely fine grain size in the matrix that increased the sinterability and strength of the final ceramic. Without aluminum additions, the matrix density was approximately 62 percent of the theoretical density of alumina. Addition of aluminum increased matrix density up to 85 percent of theoretical density. As anticipated, the composite strengths also increased with matrix density and aluminum content. Both first matrix cracking (the stress level at which matrix cracks first appear) and ultimate stress increased significantly.

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