

A STUDY OF PROPERTIES OF CARBON-CARBON COMPOSITES WITH CERAMIC POWDERS

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Introduction

Carbon fiber reinforced carbon matrix composites, or simply: C/C composites, are extremely high materials with maintain their mechanical properties up to 3,700K in inert environments and up to 2,000K in oxidizing environments. So they are developed due to the demands of the aircraft and aerospace industries. Their use as rocket propulsion components, reentry tips, exhaust cones and friction pads, leads to the evaluation of their ablation performance [1].

Phenolic resins are systematically being incorporated into carbon and graphite technology. Today they are commonly used as starting materials, in the resin-based process, for C/C composite preparation by a procedure employing pyrolysis and carbonization of resin matrix and subsequent densification. Since they are easy to handle and give considerable carbon char yield [2].

In their real applications, the study on oxidation reaction inhibition for the prediction of C/C composite working life in oxidizing environments is one of the primary concerns for the prediction of composite behaviors along with the study of thermal and mechanical properties of C/C composites. On the other hand, silicides like MoSi₂ may be more suitable for this application, as these materials have high melting points (>2300K) and excellent oxidation resistance. In addition these materials becomes ductile above its brittle-to-ductile transition (BDT) temperature of 900 °C [3], leading to the high mechanical performance at high application temperatures.

The objective of the present work is to provide an understanding of the effects of ceramic powders on the oxidation reaction inhibition and thermo-mechanical properties. DSC, TGA, SEM, porosity and density changes of the C/C composites without and with ceramic powders will be discussed.

Experimental

PAN-based high strength carbon fibers (Toray, T-300, 6K) were used in the form of plain weave from the fibers of which were treated through

commercial standard surface oxidation. The resole type of phenolic resin was used as the matrix precursors of C/C composites to be studied. The MoSi₂ powders (<1 μm, supplied from Aldrich Co.) were used as the oxidation inhibitor of C/C composites, and prepared by taking 0, 5, and 10 phr of MoSi₂ on the basis of C/C composites.

The green composites from the sixty plies of resin impregnated carbon fabrics were prepared in a hot-press at 10.5MPa. and 470K for 60min. Five subsequent densification cycles carried out by the liquid phase impregnation and carbonization of up to 1270K, were performed in order to increase the bulk density of C/C composites. The heating rate to the carbonization temperature was fixed to 2K/min. The carbonization retention time of the specimens at 1270K was 128min.

The oxidation inhibition properties of C/C composites were characterized from the weight loss changes of specimens by using TGA of up to 1170K in oxidizing environments.

The mechanical behaviors of C/C composites were characterized by the three-point bending test for flexural strength and modulus properties (s/d=16, c.h.s=1.0mm/min). The interlaminar shear strength (ILSS) of the composites between fiber and matrix and/or ceramic powders were characterized by the shot-beam test for the degree of adhesion at the interfaces (s/d=4, c.h.s=1.0mm/min).

Results and Discussion

Table I exhibits the results of bulk density (D_b , g/cm³), apparent porosity (P_a), flexural strength (FS), and flexural modulus (FM) measured as a function of the number of densification cycles for all composites studied. As expected, the bulk densities increase according to the decrease of the apparent porosities. Also, it becomes possible to observe that the increasing of bulk density (or decreasing of apparent porosity) is closely related to the growing of mechanical properties (FS and FM) of the composites. Also it is seen that at the composites made with MoSi₂, the bulk densities are higher than those of the composites-unmade with MoSi₂ as a function of densification cycles. And the increasing

of the amount of MoSi₂ in C/C composites shows the decreasing of apparent porosities of the composites. This is due to the presence of MoSi₂ in open and closed pores of the composites, as shown in Fig. 1, studied by SEM.

While it is generally accepted that good mechanical properties and long durability of the composites largely depend on fiber-matrix and/or fiber-matrix-filler interfacial adhesion in the case of the fiber reinforced matrix composites, since the transferring load stress from the matrix to the fiber would require the strong adhesion at the interface of the constitutive elements rather than high cohesive density. The degree of adhesion at the interface between fiber and matrix may be measured by the short beam test for ILSS of the mechanical behaviors.

From the ILSS results as listed in Table II, the presence and the increasing of the amount of MoSi₂ lead to the increase of ILSS of C/C composites. From which, it can be concluded that the effects of the amount of MoSi₂ on the composite properties are twofold: it increases the adherent surface areas between fibers-matrix-ceramic powders (or it decreases the porosities between fibers and matrix) and it allows the BDT behavior which is an intrinsic properties of MoSi₂.

References

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2. Knop, A. and Pilato, L.A., in *Phenolic Resins*, Springer-Verlag, Berlin, 1986.
3. Jandhyala, S., *J. Am. Ceram. Soc.*, 1993, 76, 226.

Table II. ILSS (MPa) of all composites studied as a function of number of densification.

No.	0 phr	5 phr	10 phr
1	25.0	26.0	26.5
2	26.0	27.0	28.0
3	27.0	28.0	28.5
4	27.5	28.5	29.5
5	27.5	29.0	30.0

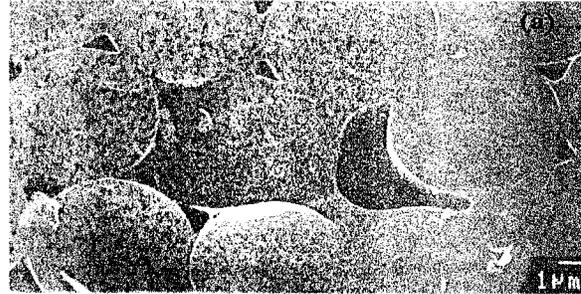


Figure 1. Scanning electron micrographs of C/C composites with MoSi₂ of 0 phr (a) and 5 phr (b)

Table I. The physical and mechanical properties of all composites studied as a function of number of densification

No.	0 phr				5 phr				10 phr			
	D_b g/cm ³	P_a %	FS MPa	FM GPa	D_b g/cm ³	P_a %	FS MPa	FM GPa	D_b g/cm ³	P_a %	FS MPa	FM GPa
1	1.475	11.0	21.0	114	1.600	9.0	22.0	126	1.700	6.0	23.0	149
2	1.520	6.0	23.0	118	1.610	5.0	26.0	130	1.705	4.5	26.5	156
3	1.535	4.5	26.0	123	1.615	4.0	26.5	134	1.725	2.5	28.0	163
4	1.535	2.5	26.5	127	1.620	2.0	27.5	137	1.730	1.1	28.5	167
5	1.550	1.5	26.5	130	1.625	1.0	27.5	138	1.730	1.0	28.5	169