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PROCESS AND WEAR OF SHORT CARBON FIBER/SILICON CARBIDE MATRIX COMPOSITE

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Process and Wear properties are investigated on a series of short carbon fiber /silicon carbide martrix(C/SiC) composite as well as pure silicon carbide. Results indicate that, while a bulk density of higher than 99% of the theoretical and a flexural strength of higher than 450MPa are measurable from the in-house fabricated SiC, the density and the strength of C/SiC composites prepared from the same process decrease with the fiber content. Preliminary results from the disk to disk sliding wear tests indicate that, under the same wear condition, the weight loss of SiC wearing against C/SiC containing 10 vol% fiber is less by about 35% than that of SiC against SiC.

1.INTRODUCTION

Silicon carbide has been used in many industries because of its excellent properties, such as hardness ,corrosion and oxidation resistance, and high temperature mechanical properties[1,2]. When wearing against metals, however, most ceramic materials, including SiC, have exhibited rather high friction coefficients, typically in the range 0.5-0.8[3]. In an attempt to reduce the friction coefficient and wear of SiC, a series of carbon fiber/silicon carbide matrix (C/SiC) composites have been fabricated and investigated in this study. Advantages of this concept include continually supplying " self-regenerative " carbon lubricant and a potential of strengthening / toughening of matrix material attributed to the high strength and high modulus of the fiber. To make use of a relatively easy process for fabrication of short fiber-reinforced ceramic matrix composites developed in the present authors' laboratory, short fibers were used in this study.

2.EXPERIMENTAL

Types and selected properties of various raw materials used in this study are listed in Tables 1 and 2. [4]

Table1. Powders used in this study

Powder	Particle size	Purity	Source
α-SiC	<4μm	>98.5%	HCST,A10
Al_2O_3	aver.1μm	>99.0%	Brand A-32
AlN	aver.1μm	>99.0%	HCST
B_4C	<10μm	>99.5%	HCST
Graph.	<2μm	>99.9%	CERAC,G-1059

HCST:HERMANN C. STARCK, INC. (USA)
Brand:City Gate Brand (Japan)
CERAC:CERAC Incorporated

Table2. Carbon fiber used in this study

Tensile strength	Tensile molulus	Density	Diameter
2960MPa	586GPa	2.16g/cm^3	7-8μm

Selection of the best sintering aids was based on density and strength

data of the products. The used sintering aids included AlN , Al_2O_3 ,B_4C and graphite.

Ethyl alcohol,n-octyl alcohol,acetone and n-hexane, were experimented to disperse the short carbon fibers (1~2 mm). The dispersing ability of a solution was judged by the 24-hour settling height of 0.05gm fiber ultrasonically dispersed in a 28 mm dia. test tube containing 40 ml dispersing solution. After a series of tests, the best dispersing agent was identified to be n-octyl alcohol.

A hot pressing system was used to fabricate SiC and C/SiC composites. Peak temperatures of 2000℃ and 2100℃ and a peak pressure of 25 MPa in 1 atm argon atmosphere were used throughout the study. For fabrication of SiC, appropriate amounts of SiC and sintering aid powders were ball-mill-mixed in ethyl alcohol, fast dried, then ground into powder, and mixed again with a small amount of ethyl alcohol to form a thick slurry. This slurry was press-molded into round disks of a fixed diameter and desirable thicknesses, followed by baking at 100℃ for 6 hours, then ready for the final hot pressing process.

For fabrication of C/SiC composite, appropriate amounts of short fibers and SiC powder with the selected sintering aid (2wt% AlN + 0.5wt% graphite) were first ultrasonically dispersed in n-octyl alcohol and rapidly dried on a heated metal plate enclosed in an evacuated container to make C/SiC "prepreg" fragments (Fig.1). Following the process for SiC, these C/SiC fragments were then mixed, with small amount of ethyl alcohol to form slurry , press molded, baked and hot pressed.

Four-point bending tests of SiC and C/SiC specimens were performed with a Instron 8562 system.

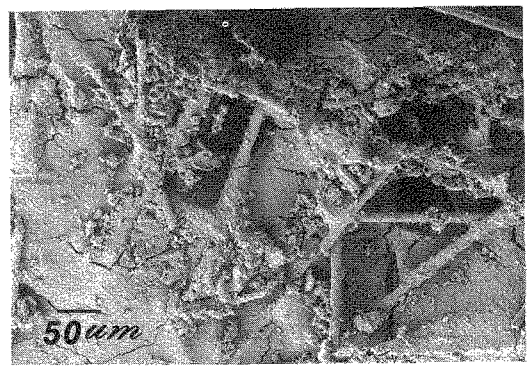
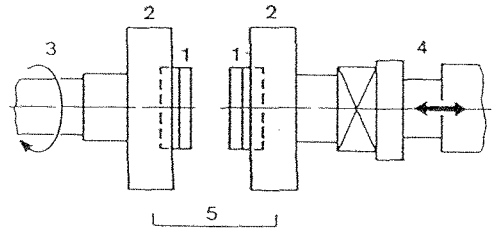
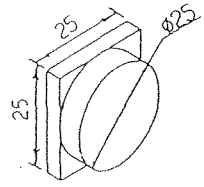


Fig.1. SEM micrograph of C/SiC prepreg fragments.

Dry sliding wear test was performed at room temperature in air on a home-made disk-to-disk sliding wear tester schematically shown in Fig.2. All SiC and C/SiC specimens for wear test were prepared by hot pressing at 2000℃ and 25MPa. The specimen surfaces were flattened using a #500 diamond wheel.



1.specimen 2.holder 3.rotating shaft
4.load 5.debris collector



unit:mm

Fig.2. Wear tester and specimen specification.

3.RESULTS AND DISCUSSION

3.1.Effects of sintering aids

Effects of single-component and two-component sintering aids on density and flexural strength of SiC hot press-

ed at 2000℃ and 25MPa are respective -ly shown in Fig.3a and 3b. The hot pressed SiC's added with AlN as a sintering aid had higher densities(97.6% of thetheoretical) and flexural strengths (about 380 MPa) than those with Al_2O_3 or B_4C.

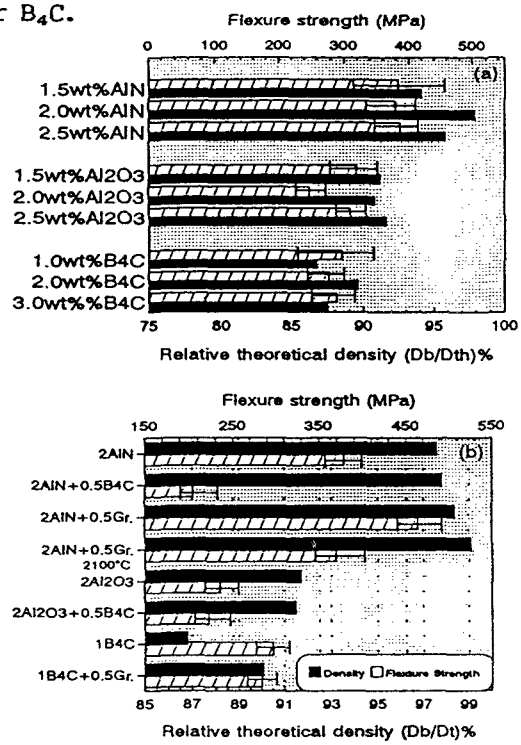


Fig.3. Effects of single-component (a) and two-component(b) sintering aids on density and flexural strength of SiC.

When 0.5 wt% graphite was added as a second component in the sintering aid, the density and the strength of SiC were further increased. For example, with 2wt% AlN plus 0.5wt% graphite as sintering aids, an SiC with a density of 98.4g/cm³ and a flexural strength of 460MPa could be obtained. When hot-pressed at 2100℃ with the same two-component sintering aids, a density of higher than 99% of the theoretical could be achieved, although the flexural strength became lower (down to about 370 MPa) due to a grain growth effect.

3.2.Density and flexural strength

Densities and strengths of SiC as well as C/SiC composites with 5,10, and 15 vol% fiber are summarized in Fig.4. The density and flexural strength of C/SiC both decreased with increase in fiber content. Using the present process which is relatively easy and has been successful in some areas,the short fibers did not strengthen, but weaken the SiC matrix. The large difference in C.T.E. between SiC (around 4.5×10^{-6}/℃) and the high modulus carbon fiber, particularly in the fiber axis direction ($<1\times10^{-6}$/℃), could cause significant residual tensile stress at the fiber-matrix interface when the composite was cooledfrom the high process temperature. In the present hot pressed C/SiC, fibers were often observed to have completely or partially separated from the surrounding matrix. This weak interface could havecaused the matrix-fiber load transfer ineffective. Most of the advanced C/SiC composites for high temperature appli cations, such as rocket nozzles, have used woven long fibers infiltrated / densified by chemical vapor infiltration (CVI) processed at much lowertemperatures.[5]

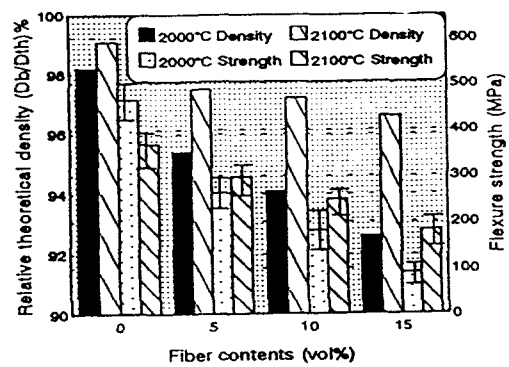


Fig.4. Density and flexural strength of SiC and C/SiC.

3.3.Wear behavior

Figure 5 shows 10-hour accumulated weight losses of SiC sliding against SiC and C/SiC. For SiC against SiC the weight loss data were averages of both disks (stator and rotor), whereas for SiC against C/SiC the weight losses of the two disks were separately measured. As shown in Fig.5, when wearing against C/SiC composites,the weight loss of SiC was always less than those of the composite counterparts. It is also shown that the weight loss of SiC wearing against the composite, compriseing 10 vol% fiber, was lower by 35% than that of SiC against itself.

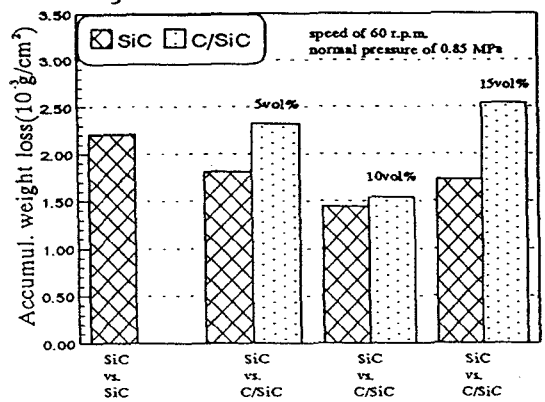


Fig.5. 10-hour accumuated weight loss of SiC sliding against SiC and C/SiC.

From the preliminary data it is found that wear behaviors of SiC and C/SiC are sensitive to two factors: 1) the relative hardness and strength, and 2) whether a carbon lubricant is present. Effect of the first factor could be seen from the fact that SiC was always less worn than the counterpart composites which are weaker and softer than SiC. Effect of the second factor is reasoned by the fact that SiC was always less worn when sliding against composites than against itself. Although the friction data are not yet obtained, the presence of carbon has shown its effectiveness in reducing wear of SiC.

4.CONCLUSIONS

1) Using the most effective dispersing agent, n-octyl alcohol, and the most effective sintering aid, 2wt% AlN plus 0.5 wt% graphite, a density of higher than 98.4% of theoretical and flexural strength of higher than 450MPa could be obtained from SiC hot pressed than that in argon at 2000℃ and 25MPa.

2) The density and flexural strength of C/SiC composites both decreased with increase in fiber content due to a less effective sintering process.

3) When sliding against C/SiC, the weight loss of SiC was less than those of the composite counterparts and less than that of SiC against SiC. Under the same condition, SiC was less worn by 35 % against C/SiC containing 10 vol% fiber than against itself.

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