

Friction and wear properties of C/C–SiC braking composites

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Abstract

Two series of C/C–SiC composites were fabricated via precursor infiltration pyrolysis (PIP) and chemical vapor infiltration (CVI) using porous C/C composites with different original densities as preforms, respectively. The tribological characteristics of C/C–SiC braking composites were investigated by means of MM-1000 type of friction testing machine. The friction and wear behaviors of the two series of composites were compared and the factors that influence the friction and wear properties of C/C–SiC composites were discussed. Results show that the friction and wear properties relate close-knit to the content of SiC and porosity. As the original preform density increasing, the content of SiC and porosity decrease, and then the friction coefficient increases obviously, the braking time and the wear rate both decrease. Preparation techniques play an important role in the tribological properties of C/C–SiC composites. Compared with PIP process, the samples from CVI have a little higher friction coefficient, shorter braking time and higher wear rate.

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Keywords: B. Porosity; C/C–SiC composites; PIP; CVI; Friction and wear properties

1. Introduction

The potential for using C/C materials in brake discs and pads has been known for fairly a long time [1]. Because of their outstanding properties, such as low density, excellent strength up to high temperatures, low coefficient of thermal expansion, C/C frictional components were applied in aircraft, racing cars and motorcycles [2–5]. However, C/C brakes suffer from high wear rate and poor oxidation resistance, which restrict its application seriously [6,7].

C/C–SiC composites, the carbon fiber reinforced dual matrices composites, introducing SiC in C/C, exhibit high and stable friction coefficients, low wear rates, high thermal shock resistance, and preferable oxidation resistance in comparison with traditional brake materials [8–10]. Nowadays, C/C–SiC composites have been demonstrated to be the top choice as the advanced brake systems.

At present, C/C–SiC can be fabricated by various methods including chemical vapor infiltration (CVI), precursor

infiltration pyrolysis (PIP), liquid silicon infiltration (LSI) and so on [11,12]. Each of the above routes displays both advantages and drawbacks. CVI and PIP are both slow densification technique and yield materials with some residual porosity. The materials fabricated by LSI often contain free silicon, which seriously affects their frictional properties [13]. And the composites from LSI display relatively poor mechanical properties [12].

In this study, two series of C/C–SiC composites were fabricated via different methods, including PIP and CVI, respectively. The friction and wear properties of C/C–SiC composites from different techniques were compared and the effects of porosity and SiC contents on the tribological properties of C/C–SiC composites were discussed.

2. Experimental

2.1. Manufacture of the composites

The C/C preforms with different original densities were produced by chemical vapor deposition process (CVD) firstly and then the C/C–SiC samples were developed via the following two methods including PIP and CVI, respectively.

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2.1.1. PIP

The preceramic polymer was polycarbosilane (PCS). At first, the preforms were infiltrated in a 50 wt.% PCS-xylene solution in vacuum. The preforms filled with precursor were then pyrolyzed in an inner atmosphere at 1600 °C for 2 h. In order to densify the composites, the infiltration-pyrolysis processes were repeated until the weight increments were less than 0.5%. Three group samples, the original densities of which were 1.03 g/cm³, 1.23 g/cm³ and 1.47 g/cm³, marked as Groups 1–3, were obtained via the PIP method. The detailed parameters of the obtained composites are shown in Table 1.

2.1.2. CVI

The SiC CVI was performed using a mixture of methyl-trichloro-silane (MTS, CH₃SiCl₃) and hydrogen. MTS was used as precursor in this study, which was carried by argon. And hydrogen was used as a dilute gas to slow the reaction rate. After deposition, the surfaces of the samples were ground about 1 mm to protect the pores from covering. The process described above was repeated until the weight increments were less than 0.5%. Three group samples, the original densities of which were 1.15 g/cm³, 1.23 g/cm³ and 1.44 g/cm³, marked as Groups 4–6, were obtained via the CVI method. The detailed parameters of them are shown in Table 2.

2.2. Characterization

Friction and wear tests were carried out on a MM-1000 friction testing machine with C/C–SiC composites as both rotating discs and corresponding stationary discs (Fig. 1). The tests would not stop until the friction coefficient was not sensitive to brake times. The testing conditions were as follows: the rotational speed 7500 rpm, the running inertia 2.6 kg m s²,

and the braking pressure 0.82 MPa. Prior to the tests, the surface of specimens and the counterparts were rubbed against each other many times to reach 80% of tangent area. At the end of tests, the linear wear was measured using a micrometer callipers with the precision of 0.01 mm.

The brake torque was obtained from the simulating system directly, and the average friction coefficient can be calculated by the following equation:

$$\mu = \frac{M}{P \cdot S \cdot r}$$

where M is the brake torque, P is the brake specific pressure, S is the frictional area when braking (22.8 cm²), r is the average friction radius (3.3 cm).

The worn tracks of the samples were observed by a JSM-64600 SEM. The densities of samples were measured by Archimedeian method, from which the interrelated fractional open porosity can be calculated. The weight increment of samples was reckoned to be the content of SiC.

3. Results and discussion

3.1. Density, SiC content, and porosity

The density, SiC content, and porosity of samples from different methods are shown in Tables 1 and 2. Despite of different original preform densities, the final densities of samples are of little difference. For the samples with similar original density from different method, the final densities are almost the same. All the brake pairs are with approximate final densities, which could cooperate to work in this study.

It can also be seen that both the SiC content and porosity decrease obviously with the increase of the original densities, as

Table 1
Density, SiC content, and porosity of samples from PIP.

Group		Original density (g/cm ³)	Final density (g/cm ³)	SiC content (%)	Porosity (%)
1	Rotating disc	1.03	1.883	45.20	15.08
	Stationary disc	1.03	1.886	42.43	14.99
2	Rotating disc	1.23	1.897	35.17	8.64
	Stationary disc	1.23	1.902	38.10	7.64
3	Rotating disc	1.47	1.892	22.31	1.81
	Stationary disc	1.47	1.897	22.50	1.68

Table 2
Density, SiC content, and porosity of samples from CVI.

Group		Original density (g/cm ³)	Final density (g/cm ³)	SiC content (%)	Porosity (%)
4	Rotating disc	1.15	1.921	41.45	13.59
	Stationary disc	1.15	1.916	44.91	13.72
5	Rotating disc	1.23	1.885	39.03	10.89
	Stationary disc	1.23	1.848	40.43	12.38
6	Rotating disc	1.44	1.886	24.80	3.15
	Stationary disc	1.44	1.865	23.59	3.71

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