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Study on the Fabrication and the Properties of C/C Composite from Clutter Chopped Carbon Fiber by Warmer-Molding Technology

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Abstract

Carbon/Carbon composite was been manufactured by the technology of warmer-molding process of clutter chopped carbon fiber, using phenolic resin as an adhesive. The degree of graphitization, the microstructure and the friction properties were studied. The results show that the clutter chopped carbon fiber fully scatter in the Carbon/Carbon composite and the degree of graphitization of phenolic resin can reach up to 86.2%, this matrix carbon can form the continuous and stable graphitic thin film on the friction surface during braking process so that the composite has fine friction properties and low wear rate.

Keywords : *Carbon/Carbon Composite, Warmer-molding-pressure, Friction properties*

1. Introduction

Carbon/Carbon (C/C) composite has been an ideal friction material for its excellence properties of low density, high thermal conductivity, low coefficient of thermal expansion, good friction property and high strength at high temperature [1-3]. C/C composite is composed of a matrix carbon reinforced by 1-D or mult-D carbon fibers. The manufacture process is infiltrated the carbon into the carbon fiber preform. There are two methods to produce C/C composite. It is known as liquid infiltration and chemical vapour infiltration (CVI), respectively. C/C composite made by CVI technology has excellence friction properties, thus make CVI technology a main method to produce carbon brake discs [4].

Though there are many advantages of carbon structure and stability friction property for CVI carbon matrix, there are still many disadvantages of low deposited efficiency, long processing time and high cost [5-8]. Therefore, it is the important for carbon brake disc to decrease the producing cost and time.

Warmer-Molding-Pressure process for manufacture of C/C composite is an effective method to decrease the producing cost and time [9]. The key of this method is to select an adhesive with high carbon yield and high graphitization-degree. In this paper, C/C composite is manufactured by the warmer-molding-process technology of clutter chopped carbon fiber, using phenolic resin as an adhesive, to develop a new low cost method.

2. Experimental

2.1. Materials

The clutter chopped carbon fibers with 10 mm long were 12 K-PAN based T700 from Toray, Japan, which cut short and heat-treated at high temperature. The adhesive was phenolic resin.

2.2. Preparation of C/C composite

The clutter chopped carbon fibers were dispersed in water with powdered phenolic resin at a ratio of 6:4 by weight. After full mixed, the water was discharged from the mixed vessel. The randomly oriented chopped carbon fiber containing phenolic resin and some water were put into a mold and compressed to remove a part of water at the sulfidation equipment. When the demanded thickness was obtained, the temperature was increased to 170°C at a rate of 5°C/min and hold for 2 hrs to make the phenolic resin be solidified. Afterwards, the temperature was decreased to room temperature. So a green specimen was prepared.

After all green specimens were carbonized at 800°C, a resin vacuum impregnation/high pressure carbonization cycle was performed three times. Finally, all specimens were graphitized at 2300°C for 1 hr. The densities of these specimens were up to 1.78 g/cm^3. The total time for making the C/C composite was about 6 days.

2.3. Measurement of properties of C/C composite

To study the property of C/C composite, the test specimens were made by cutting the C/C composite from the central, and polished. Then optical microscope equipment (Polyvar-MET) was used to observe its microstructure and the friction surface. The Rigaku D/Max-3C x-ray diffraction

equipment was used to measure the graphitized degree with Cu as the target, Si as the inside standard substance. The Model MM-1000 friction test machine was used to measure the friction and wear properties. The dimension of the test disc was outer diameter of 75 mm, inner diameter of 53 mm, thickness of 10 mm. The test condition was at rotate speed of 7500 r/min; inertia of 0.03 kg·m·s^2; Pressure of 1.0 MPa. After 10 times brake, the line wear quantity of test rings was measured using a micrometer.

3. Results and Discussion

3.1. The graphitized degree of C/C composite

The degree of graphitization is an important parameter for carbon brake disc. The result has been proved that the rough laminar (RL) structure of three pyrolytic matrix carbon (smooth laminar, rough laminar and isotropic texture) is generally desired for braking application [10]. The reason is that the RL matrix is the nearest to the ideal graphite state structure, it possesses the properties of high and steadied friction coefficient (0.30-0.34), and low wear. During the producing of carbon brake disc, it is a common used method to determine the degree of graphitization of C/C composite by using of X-ray diffraction to deduce the final friction properties. At present study, the result of X-ray diffraction pattern of d(002) crystal lattice of carbon is shown in Fig. 1.

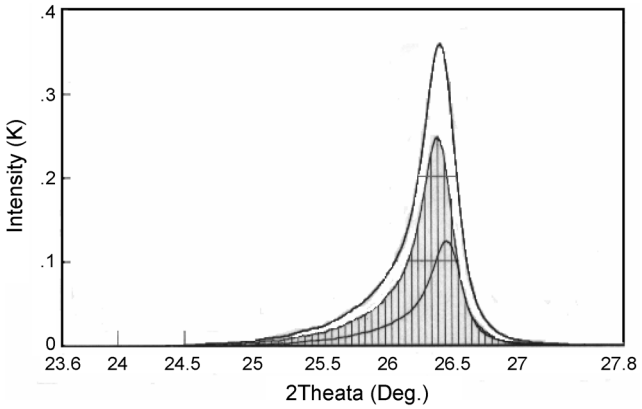

Fig. 1. X-ray diffraction pattern of C/C composites.

Table 1. Results of the diffraction curve integral.

	D(002)			
	2θ	θ	d	Degree of graphitization (%)
Half-High-Width	26.372	13.186	3.361	91.2
Gravity	26.238	13.119	3.377	73.4
Peak	26.395	13.198	3.359	94.1
Average of degree of graphitization				86.2

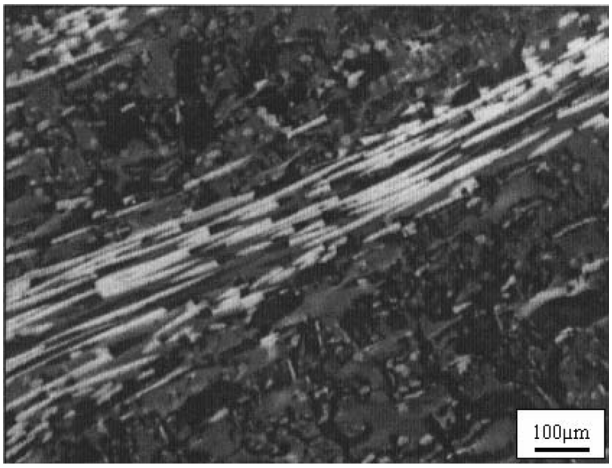

Fig. 2. The micrograph of C/C composite.

From Fig. 1, the degree of graphitization can be calculated by the diffraction curve integral.

From these results, it can be concluded that C/C composite manufactured by the technology of warmer-molding-pressure process of chopped carbon fiber, using phenolic resin as an adhesive has a high degree of graphitization (86.2%).

3.2. Microstructure of C/C composites

C/C composite composing of carbon fiber and carbon matrix has all advantages of carbon, and that overcome the disadvantages of carbon. Thereinto, carbon fiber is a reinforced phase, carbon is a matrix phase. The uniformity of carbon fiber scattering in the body of C/C composite will mainly affect its properties. To get a wide view for investing carbon fiber distributing in the C/C composite, the low magnification micrograph is utilized. The micrograph is shown in Fig. 2.

Fig. 2 shows that carbon fibers evenly scatter in matrix carbon. Although some carbon fibers still exist in bunch state, the carbon fibers in bunch are surrounded by matrix carbon. Therefore, this will not significantly affect friction property of C/C composite.

3.3. Friction and wear properties of C/C composite

The friction and wear property of C/C composite is an ultimately factor that determined whether it can be used as brake disc. The friction and wear property of C/C composite was tested using the Model MM-1000 friction test machine. Fig. 3 shows the dimension of the friction test rings. Fig. 4 shows the picture of friction test rings.

At the beginning of test, the friction test rings were first grinded in. Then, the friction test rings were used to brake test 10 times at a speed of 7500 r/min with 0.03 kg·m·s^2 as the inertia, 1.0 Mpa as the pressure. The character curve of

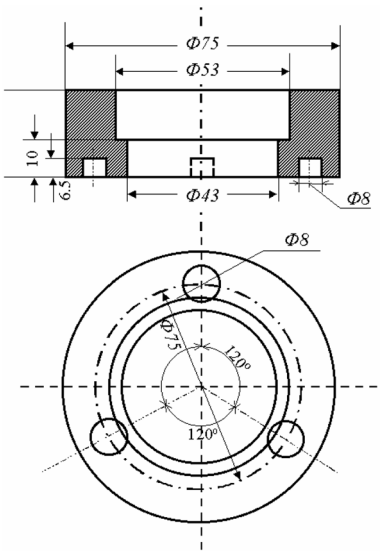

Fig. 3. The dimension of friction test rings.

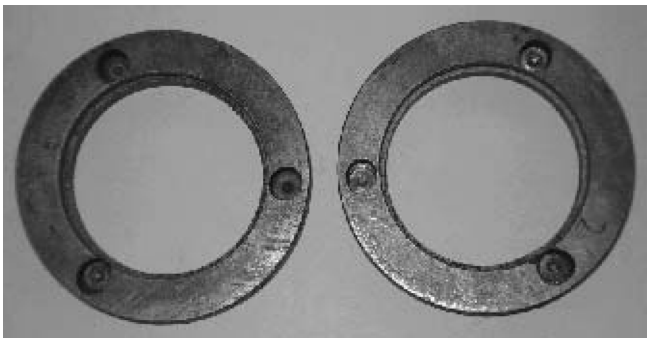

Fig. 4. The picture of friction test rings.

braking test is shown in Fig. 6. The friction and wear values are listed in Table 2.

The friction curve shows that the C/C composite possesses not only a smooth and steady brake curve and stable friction coefficient (0.32), but also a low wear rate.

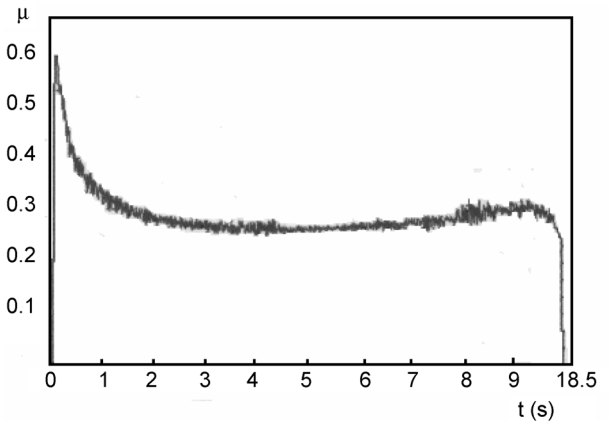

Fig. 5. The curve of brake test of C/C composite.

Table 2. The friction and wear values.

Brake times	Friction coefficient	wear (μm/times)	Brake time (s)
1	0.314	1.92	16.76
2	0.295	1.80	18.10
3	0.296	1.82	19.04
4	0.302	1.85	18.40
5	0.313	1.92	16.82
6	0.302	1.84	17.62
7	0.305	1.87	17.62
8	0.325	1.98	16.58
9	0.324	1.98	16.28
10	0.399	2.44	13.30
Average	0.317	1.94	17.05

Fig. 6 shows that micrograph of friction surface after 10 times brake.

Fig. 6(a) is the 100 times magnification micrograph. Part A is the exposure carbon fibers. Fig. 6(b) is the 200 times magnification micrograph of part A. It is obvious that the friction surface have formed a continuous and stable graphitic

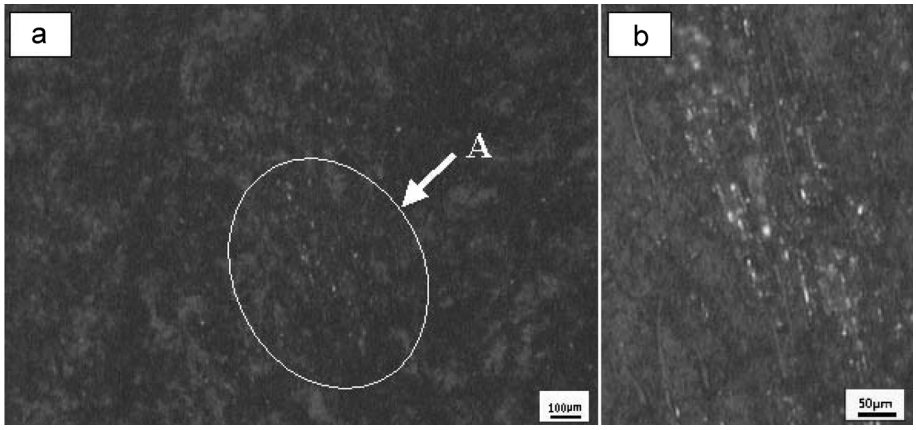

Fig. 6. Micrograph of friction face. (a) 100-magnification (b) 200-magnification

thin film during braking process. At the same time, there is not wear fiber in the friction surface.

The main reason for this phenomenon is that the degree of graphitization of this phenolic aldehyde resin used at present study is high up to 86%, which close to the matrix carbon made by CVI technology and reinforced fiber full scatter. During braking, the graphitic thin film can be formed easily so as to insure friction coefficient stability and low wear rate.

4. Conclusions

1) The uniformity of blend of carbon fiber and phenolic resin is even. The carbon fibers are fully and evenly scatter in the body of C/C composite. C/C composite manufactured by the technology of warmer-molding-pressure process of clutter chopped carbon fibers, using phenolic aldehyde resin as an adhesive has a high graphitization degree. It is high up to 86.2%.

2) During the brake process, the matrix carbon with the high graphitization degree form the continuous and stable graphitic thin film to make the fine friction property and low friction wear. The average friction coefficient of the C/C composites is 0.32. The average friction wear is about 1.94 μm/times.

3) In addition, this technology has the advantages of short prepared time, and low cost.

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