THE EFFECTS OF CARBON MATRIX TOUGHENING MODIFICATION ON THE MECHANICAL PROPERTIES OF C/C MATERIALS

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Introduction

The toughening modification of carbon matrix has always been the focus of carbon/carbon composite materials. Carbon matrix toughening modification helps to improve the interfacial toughness and interlaminar shear strength. The addition of fine particle graphite and expanded graphite powder in the carbon matrix may improve the elongation rate of carbon materials and play a role of toughening the matrix.

Experimental

For the modification of pitch carbon and resin carbon matrix C/C materials, keep the combined weight of fine particle graphite and expanded graphite powder at a constant level of 8% of the total carbon precursor and vary the ratio of fine particle graphite and expanded graphite in the formulation; prepare the ethanol solution in which the carbon cloth was impregnated. The prepreg was then processed and carbonized. In the case of CVD carbon matrix modification, disperse the graphite powders inside the ethanol solution of polyvinyl alcohol, which has an extremely low tar residue of 1~2%; then the carbon cloth was impregnated and processed and densificated through CVD process.

Results and Discussion

1. Toughening modification of pitch carbon matrix

Table 1 is the mechanical properties of pitch carbon matrix C/C materials

It is shown in table 1 that the addition of graphite powders can obviously improve the mechanical properties of C/C materials, such as fiber strength transfer, tensile elongation and shear strength.

As the fine graphite particles are dispersed inside the carbon matrix, no large size microcrystalline structure could form in the heat treatment and graphitization process. Fine graphite particles have a highly sliding effect and expanded graphite particles are highly deformable; as a result of both of them, percolated among the microcrystals inside the carbon matrix, in the process of microcrack growth and convention when the material deforms under tension, the stress at crack tip is released and the crack stops or bifurcates into smaller microcracks; thus the formation of larger cracks is avoided.

2. Toughening modification of resin carbon matrix

Table 2 is the mechanical properties of resin carbon matrix C/C materials

It is shown in table 2 that the mechanical properties of C/C materials were greatly improved as a result of resin carbon matrix toughening modification. However, the mechanical properties are still low compared with those of pitch carbon matrix materials; it can be explained by glassy carbon structure, which is inherently porous and rich in defections.

3. Toughening modification of CVD carbon matrix

Table 3 is the mechanic properties of CVD carbon matrix C/C materials

It is shown in table 3 that the fiber strength transfer and tensile elongation of modified materials were obviously improved, while their shear strength slightly decreased. It may be explained by the fact that graphite

powders might have a toughening effect inside the CVD carbon matrix while they might have a negative effect on the interphase.

Conclusions

Fine particle graphite powder is highly self-lubricating and deformable; it may bifurcate and stop crack propagation in carbon matrix, so it can significantly improve the fiber strength transfer and interlaminar shear strength of C/C composite materials. Expanded graphite powder is highly deformable in volume, and it can significantly improve the tensile elongation rate of C/C materials. Among the three modified carbon matrix C/C materials, pitch carbon matrix composite had the best modification effect, with its shear strength and fiber strength transfer rate being 19.5MPa and 62%, respectively.

Table 1. Mechanical properties of pitch carbon matrix C/C materials

Serial Number	Ratio of fine particle graphite against expanded graphite powder	Heat treatment temperature ℃	Fiber strength transfer		Tensile elongation rate		Interlaminar shear strength	
			%	Cv	%	Cv	MPa	Cv
1	20: 1	900	48.4	9.0	0.76	10	13.8	11
2	10: 1	2500	62.0	8.4	0.85	9.0	19.5	9.0
3	5: 1	900	42.0	6.5	0.83	8.5	9.1	6.5
4	0: 0	1500	40.0	7.4	0.55	7.3	14.6	10
5	0: 0	2500	45.0	5.4	0.48	6.3	16.9	8.0
6	10: 1	1500	52.6	6.0	0.78	7.0	17.2	7.5

Table 2. Mechanical properties of resin carbon matrix C/C materials

Serial Number	Ratio of fine particle graphite against expanded graphite powder	Heat treatment temperature ℃	Fiber strength transfer		Tensile elongation rate		Interlaminar shear strength	
			%	Cv	%	Cv	MPa	Cv
1	5: 1	1500	25.0	4.5	0.40	5.7	9.40	10
2	20: 1	2500	36.0	9.0	0.36	8.5	8.70	9.0
3	10:1	900	30.2	7.4	0.45	6.4	11.0	8.3
4	0: 0	900	17.6	6.4	0.31	7.5	9.10	8.0

Table 3. Mechanic properties of CVD carbon matrix C/C materials

Serial Number	Ratio of fine particle graphite against expanded graphite powder	Heat treatment temperature ℃	Fiber strength transfer		Tensile elongation rate		Interlaminar shear strength	
			%	Cv	%	Cv	MPa	Cv
1	0: 0	900	15.0	6.0	0.28	4.6	18.3	5.6
2	10: 1	900	40.3	5.6	0.41	7.6	17.3	5.4
3	20: 1	1500	45.4	4.6	0.28	5.4	16.5	4.7
4	5: 1	2500	31.6	4.0	0.36	4.5	8.90	6.4