FORMATION AND DEVELOPMENT OF CARBON MATRIX IN FINE WEAVE PIERCED C/C COMPOSITE

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Introduction

C/C composite is used in many fields because of its low density, good high temperature mechanical performance, refractory, anti-heat seismic and designable properties. It has been the first selection to manufacture crucial components in many fields. The quality of C/C composite is relative to the reinforcement and its structure. Some properties such as tensile strength, wear resistance, anti-scorch and particle erosion resistance are affected evidently by the type, distribution, content of carbon matrix and the state of interface between the carbon matrix and the carbon fiber. The formation process of carbon matrix during the manufacture of the composite has direct influence on the distribution and configuration of the carbon matrix. So the study of the formation process and performance of carbon matrix during each compounding stage is very helpful to improve its formation technology, performance and quality. This problem is researched in the article, focusing on the fine weave pierced C/C composite.

Experimental

The fine weave pierced C/C composite is based on the fine weave pierced fabric reinforcement framework. The soaker is coal pitch. The sample is taken from the manufacturing composite after the processing of pitch impregnation and carbonization (graphitization). The configuration and distribution of carbon matrix are observed by SEM and metallography.

Results and Discussion

Formation and development of carbon matrix

CT non-destructive inspection and theoretical computation show that the pitch fills up the pores among the carbon fiber on the whole after impregnation under vacuum and low pressure. Sample examination of the carbonized composite indicates there is no obvious carbon matrix in the relatively big pores that exist between the xy-plane carbon cloth layers, between the xy-plane carbon cloth and the z-axial carbon fiber bundle, and at the carbon fiber cross-site of the xy-plane carbon cloths. The carbon matrix is mainly formed in the pores among the carbon fiber filaments. The carbon matrix layer is paralleled to the axis of carbon fiber, becoming POG structure. The interfacial bonding strength is weak between matrix and carbon fiber. At the fracture surface plenty of carbon fiber surface without matrix carbon are exposed. There is no obvious carbon matrix at the external surface of carbon fiber bundle. This indicates that the z-axial fiber bundle and the xy-plane carbon cloth layer exist independently after the stage, and the bonding strength between them is weak.

The results after later impregnation/ carbonization show that the carbon matrix continues filling in the pores among the filaments. The quantity of carbon matrix increases remarkably than that in the preceding stage. There is obvious carbon matrix at the outer surface of the carbon bundle. It becomes popular that the z-axial fiber bundle and the xy-plane carbon cloth layer are connected by the carbon matrix. This indicates that there is somewhat bonding strength between the z-axial fiber bundle and the xy-plane carbon cloth layer. However, there is no evident carbon matrix in the relatively big pores between the xy-plane carbon cloths.

The results after subsequent processing cycles indicate that the carbon matrix is formed in the unfilled pores within the fiber bundles so that the interfacial bonding between the fiber and carbon matrix is strengthened. The most evident character after the stage is that the carbon matrix is formed in the relatively big pores between the xy-plane carbon cloth layers and between the z-axial carbon fiber and the xy-plane carbon cloth layers.

With increasing processing cycles , the material density increases gradually, even up to 2.0 g/cm^3. From the samples taken at different stages we can see that the smaller pore can be more easily filled by carbon matrix . As a whole, the carbon matrix presents an inlaid structure state. The appearance character is relative to the structure of the pores and the carbon matrix formed during the former stages. The carbon matrix layers are distributed mainly along the carbon fiber axis at the field where the filaments of the fiber bundles are compact. There is distinct crevice between the xy-plane carbon cloth layers or between the z-axial fiber bundles and the xy-plane carbon cloth layers, where the carbon matrix layers are distributed mainly along the wall of the pore. The carbon matrix layer and the crevice have the same direction when the crevice is small.

When the distance between the carbon cloths is comparable to the distance between the z-axial fiber bundles, the carbon matrix layers tend to present "X" model distribution. That is to say at the field near the z-axial fiber bundle or xy- axial carbon cloth, the carbon matrix layer and the nearby z-axial carbon fiber bundle or xy-plane carbon fiber cloth have the same direction and there are two intersecting microcracks with 45° angle to the z-axial fiber bundle(fig.1). The carbon matrix layers on both sides of the microcrack have the same alignment. If the carbon matrix pore in the big hole closes to some extent, the carbon matrix formed in the follow-up stage then presents "onion" model ply distribution. In fact, the contour of the carbon matrix connecting the carbon cloth layers and the z-axial fiber bundles is a "solid of revolution". Its axis is the z-axial fiber bundle and its external outline is the intersecting microcrack. The carbon matrix is wrapped around the z-axial fiber bundle layer by layer like an onion.

Discussion

The formation and development of carbon matrix are related to the character of the soaker pitch. During the heating, melting, decomposing and carbonizing process, the surface tension of liquid pitch is very strong. So it needs a very high pressure that can make the decomposed gas escape from the pitch. When the pressure of environment is low, the bubbles formed in the liquid pitch during the carbonization expand gradually and rupture when the pressure inside bubble is greater than the surface tension. The bubble cannot expand when the space is limited. As the temperature increases the pitch is decomposed, carbonized and coked along the space wall. So during the former low-pressure compounding stages even though the pitch fills in the big and small pores among the fabric, the pitch in the big pores cannot form carbon matrix because the bubbles expand too big under the effect of surface tension. The pores within the fiber bundle are small, so the bubble cannot expand too big. The result is that the carbon matrix is easily formed in them. Thus the carbon matrix is formed mainly inside the fiber bundles during the early stages of processing. It is easy to form carbon matrix parallel to the fiber axis because of the small contact angle between the pitch and the carbon fiber and the easy infiltration. As the growth of carbon matrix and turning small of the pores within the fiber bundle , the carbon matrix is formed gradually in the relatively big pores between the carbon cloths or between the carbon cloth and the z-axial fiber bundle during subsequent processing cycles. However, the carbon matrix layer is easy to be formed along the wall of the pores. So the configuration of the carbon matrix formed in the later period is easy to be affected by that of the carbon matrix formed in the earlier period. At the same time, the "onion" model layer distribution is easy to be formed in the pore that closes to some extent. In the pores where the distance between the xy-plane carbon cloth layers is equivalent to the distance between the z-axial fiber bundles, there are some big open holes at local field and the z-axial fiber bundles array in it. So the carbon matrix is easy to be formed piece by piece along xy-plane carbon cloth and the z-axial fiber bundle. Microcracks are formed at the boundary of the carbon matrix of the two directions, presenting "X" model distribution as shown in fig.1.

Conclusions

1. The carbon matrix in different fields of fine weave pierced C/C composite is formed in different processing stages.Early processing cycles mainly form carbon matrix inside fibre bundles.
2. The configuration of carbon matrix is relative to the compounding process, fabric structure, carbon fiber state, distribution and the configuration of the carbon matrix formed in the former stage. It presents not only "X" model distribution but also "onion" model distribution. As a whole, the carbon matrix presents an inlaid structure state.
3. The carbon fiber and the matrix are combined very tightly in fine weave pierced C/C composite. Generally the cracks distribute inside the carbon matrix.

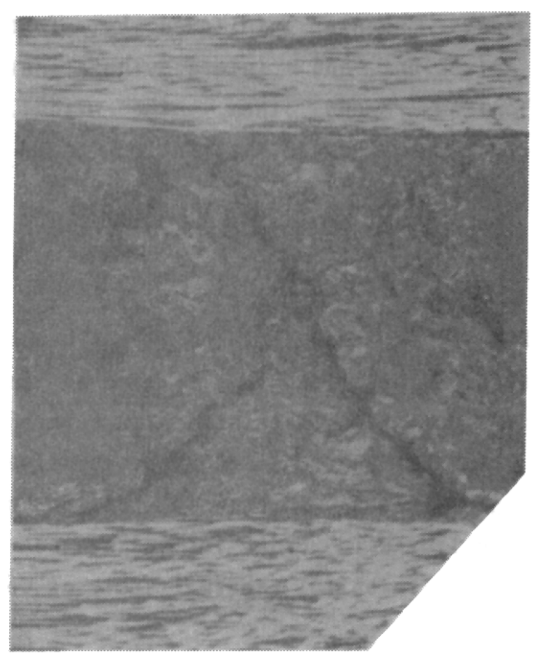

Fig.1 "X" model distribution of carbon matrix