# THE FRACTURE FEATURES OF 2-D C/C COMPOSITES

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## Introduction

Carbon/carbon composites (C/C) are widely used in such components as missile nose-tips, rocket motor nozzles, and airplane brake disks etc. because of their excellent resistance to heat-erosion and abrasion. These applications, which do not demand high mechanical performances, mainly emphasize some of special properties of C/C composites, e.g. , the capability of high temperature, thermal-erosion resistance, stable friction and wear, and low density, and so on. Currently, one of the most popular research on C/C composites is adopting them as high-temperature structural materials.[1] Therefore, the issue of improving the mechanical properties requires to be focused on. On the other hand, there are many factors that influence the mechanical properties of C/C composites. In addition to the instinct properties of reinforce fibers and the weave pattern of preforms, the fabrication technology and the materials density and the structure of carbon-matrix, as well as the interfaces between fibers and matrix all contribute to the materials' capabilities directly. It explains why numerous researchers attempt in this field by different ways, such as reference [2-3] have discussed on matrixes and interfaces respectively, while this paper inquires into a new failure mode on the basis of experimental results.

## Experimental

The preforms used in the experiments were achieved via laminating 1K carbon-cloth, which were made in Jilin Carbon Plant of China. Their volume density of fibers is 1.74 g/cm$^3$, and the thread diameter is 6-8 $\mu$ m. The fiber volume fraction of preforms was controlled to 40%. The preforms were densified via chemical vapor infiltration (CVI) technique, and propylene had been employed as infiltration gas, and the infiltration temperature was limited to 800—1100℃. The final density of experimental workpieces is 1.70—1.73 g/cm$^3$. The samples used for flexural property tests were cut from the workpieces. The results of performance tests are shown as Table 1.

It can be seen that the sample 3 possesses the flexural strength by 10—25% higher than that of the other samples. By observing its fractograph, some differences have been found between sample 3 and the others, as illustrated in figure 1. The fracture of the sample 3 is caused by neither unsticking fibers and matrix nor brittle rupture of fibers, but the damage inside matrix which results in forming new interfaces between the layers of matrix. It is due to the delamination of the new interfaces leads to material failure.

Table 1 The flexural performance by different CVI processes

| Sample | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Strength(MPa) | 213.3 | 218.8 | 241.6 | 189.4 |
| Modulus(GPa) | 28.4 | 27.7 | 27.6 | 25.3 |
| Deflection(mm) | 0.49 | 0.57 | 0.64 | 0.58 |

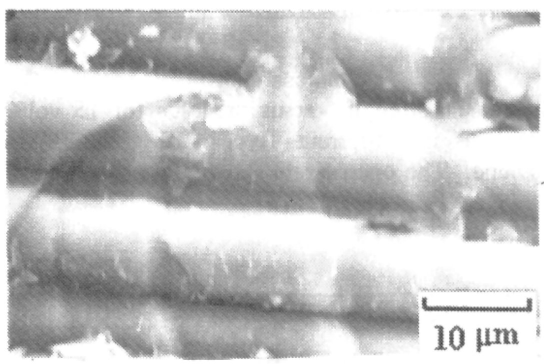


Figure 1 The delamination of pyrocarbon layers

## Analysis and Discussion

The pattern of this mentioned fracture has following features.

(1). This kind of failure occurs inside matrix, rather than on fiber-matrix interfaces.

(2). It can be seen from the fracture-section that the crack propagation inside matrix is not in straight line, and the extending direction is also altered similar to meeting the fiber in the extension process, which is taken place in different pyrolytic carbon layers instead.

(3). This fracture involves the phenomena similar to the fiber-matrix debonding.

According to the above features, it can be concluded that the layers, causing the steped delamination inside the matrix, are also a kind of interface similar to that between fiber and matrix, which can be called the "second interfaces". It is the separation of "second interfaces" leads to the final failure of the materials. This viewpoint has some difference with the investigation of traditional fracture modes of C/C composites. In terms of traditional fracture mechanism, the C/C composites are fragile instinctively, and the obvious brittle failure will occur in the condition of strong bonding strength among fibers and matrix. That is to say, applying the external load, cracks are formed initially in the matrix and gradually extended to the interfaces between fibers and matrix, and then fibers are run through and broken directly since the strong bonding interface. As for proper fiber-matrix bonding strength, cracks will turn at the time they propagate to the fiber-matrix interfaces, next cause interfaces to debond, and finally break fibers. This will just result in the so-called "pseudo-plasticity". However, the view that failure is caused by the delamination of "second interface" regards that though it is not easy for the interfaces to be damaged on load in the case of a strong fiber-matrix bonding that exists in C/C composites, the bonding strength between carbon layers of the matrix may be lower than that of interface of fiber-matrix because the carbon matrix itself is in laminal structure (showed as figure 2). Therefore, when exerted a load, cracks will propagate in those carbon layers that have lower bonding strength (as figure 2b) with the result of delamination, and turn direction when the bonding strength becomes strong, which has the effect similar to

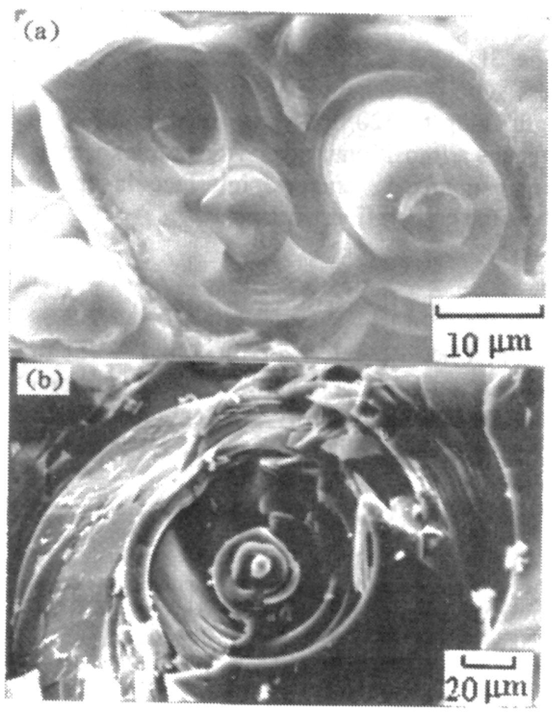


Figure 2 The laminal structure of pyrocarbon

fiber debonding from matrix. So the performances of materials are improved consequently. Of course, if each layer of the matrix carbon bonded very closely (as figure 2a), which is the usual condition, it is difficult to form the second interface. In this circumstances, the brittle fracture is inevitable and no pseudo-plasticity exhibits. In reality, there exit different pyrocarbon structure in matrix since the infiltration conditions are changed during CVI process. Generally, several fracture mechanism will be found in a fractograph, and one of them may take the main position. As for the experimental conditions of sample 3, the formed pyrocarbon is just to meet the factors of "second interface". This special fracture mode can be clearly seen. Under other conditions, the trace of the "second interface" exits also, such as in figure 2a. Certainly, it must be pointed out that only the appropriate bonding strength relationship between carbon-matrix laminations and fiber-matrix interfaces, which requires continue study, can make improvement on properties of the material.

## Conclusion

When the fiber-matrix interface has stronger bonding strength than carbon-matrix layers, the fracture can be caused owing to the separation of second interfaces. In this case, the performances of the material are improved, and at the same moment, the material displays certain " pseudo-plasticity", as similar to fibers debonded with matrix.

## Reference

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