# A Investigation on the Interfacial Microdebonding Properties in C/C Composites and the Relation to the Macroscopic Mechanical Properties

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## Instruction

It is widely concerned that the interfacial properties of C/C composites and the relation to the macroscopic mechanical properties. Generally Scanning Electronic Microscopy (SEM), Transmission Electronic Microscopy (TEM), and Metallographic Microscopy are used in the investigation of the interfacial properties of C/C composites. However, all these methods can only provide the information about the exterior characteristics of reinforcing fiber and matrix, the bonding state of interface, and have no way to evaluate the bonding state between fibers and matrix quantitatively. The writer considers the microscopic structure, which effects on the macroscopic properties of C/C composites, includes the interfacial bonding state of fiber bundles and surrounding matrix carbon, besides the interfacial properties between filament and matrix in the fiber bundles according to the investigation experience on C/C composites. The interfacial bonding property and the relation to the macroscopic mechanic properties between z-direction (z-D) filament and the surrounding matrix carbon and between z-D fiber bundles and surrounding material in the bundle of fine weave pierced C/C composites are tested. Some preliminary investigation results are introduced in this paper, by using the recently developed technique of *in situ* interfacial strength test.

## Experimental

The materials used in this paper were high-density fine weave pierced C/C composites. The specimen was prepared by cutting 3.0mm thick piece (filament pulled through) and 0.8mm thick piece (yarn bundle pulled through) (an internal-slitter was used) from the z-D fine weave pierced C/C composites, in the direction perpendicularly to z-D. The Interfacial Microdebnding Force (IMF) not only between single z-D carbon fiber and surrounding matrix, but also between z-D fiber bundles and surrounding matrix (or xy-plane carbon texture) were tested respectively, by using two in situ interfacial strength test instruments after the cutting faces were milled and polished. The interfacial bonding strength was achieved by finite-element analysis method.

## Results and Discussion:

The preliminary investigation results, by testing the interfacial properties of two C/C composites with the same texture parameters that manufactured by the same processing technology, gives the rules of interfacial bonding force between carbon filament and matrix in the z-D fiber bundles as follows:

(1) The interfacial properties in different regions are similar for the same kind of composite;
(2) The interfacial strength of peripheral region is less than that of interior region in z-D fiber bundles;
(3) The macroscopic tensile strength is high when the interfacial bonding between carbon filament and matrix is strong in composites.

In addition to the interfacial microdebonding strength between z-D carbon fiber bundles and surrounding matrix (or xy-plane texture) of three groups of composites, the interfacial microdebonding force between the interior filament and surrounding matrix of z-D fiber bundles are also tested. The test results are listed in table 1.

Table 1 shows that, the stronger the interfacial bonding between the interior filament and surrounding matrix carbon of z-D fiber bundles, the weaker the interfacial boding between z-D fiber bundles and their surrounding matrix (or xy-plane carbon texture). This reflects that, the matrix carbon has different distribution and structure inside of z-D fiber bundles and in the voids between fiber bundles and xy-plane carbon texture, and the level of bonding force between carbon fibers and matrix or the interfacial force of matrix are different in the different composites.

The fact that peripheral interfacial properties are some different from interior ones in fiber bundles may bear relation with the structural characteristics of the fine weave pierced C/C composites and manufacturing technology. It is well known that high-density C/C composite are manufactured via repeated working procedures of pitch impregnation, carbonization, and graphitization at elevated temperature. And its matrix carbon in different regions formed in different working procedures mentioned above. The matrix carbon, formed from impregnated pitch during the earlier procedures, exists mainly in the voids between interior fibers of fiber bundles, but the matrix carbon in the larger voids between z-D fiber bundles and xy-plane carbon texture is relatively less. With the densification of the composites, in addition to fill the voids that is not full-filled in the fiber bundles continuously, matrix carbon gradually permeates z-D fiber bundles and forms high-density C/C composites finally. The difference of the forming mechanisms of matrix carbon between the interior and peripheral region of z-D fiber bundles and the structures of matrix carbon formed under low and high pressure perhaps results in the different interior, peripheral, and exterior interfacial properties of fiber bundles. In addition, if more matrix carbon were filled in z-D fiber bundles, less would be filled in the voids between z-D fiber bundles and xy-plane carbon texture, considering for different composites the initial texture volume density and final material density are similar. Therefore the stronger the interfacial bonding between the interior filament and matrix, the weaker the interfacial bonding between z-D fiber bundles and surrounding matrix (or xy-plane carbon texture).

The difference of interfacial properties mentioned above takes evident effect on the mechanic properties of C/C composites. The relation of interfacial bonding strength between z-D fiber bundles and surrounding matrix (or xy-plane carbon texture) in the C/C composites, which is manufactured with same raw materials and in the same batch, and macroscopic properties relation value is listed in table 2.

Table 2 shows that the lower the interfacial debonding strength in the z-D, the higher the tensile strength for high-density C/C composites. Thus in order to improve mechanic properties in the z-D of high-density C/C composites, the matrix carbon should be controlled to form in the interior of fiber bundles as much as possible, in the exterior of fiber bundles as little as possible.

## Conclusions

1. The interfacial microdebonding property of z-D fiber bundles has the different principle of variation from that of the carbon filament.
2. A certain corresponding relation exists between z-D interfacial properties and macroscopic tensile strength.
3. The interfacial microdebongding technique can be used to quantitatively measure the interfacial properties of C/C composites.

## References


[1] J. S. Wang, A Preliminary Investigation on Quantitative Evaluation of the Interfacial Bond Properties in C/C composites. 22nd Biennial Conference on Carbon, 1995.

[2] J. S. Wang, Formation and development of Carbon Matrix in Fine Weave Pieced C/C composite, 23rd Biennial Conference on Carbon, 1997.


Table 1. Interfacial Properties of Composites

| Materials | IMF | | DS (MPa) |
|---|---|---|---|
| | F(0+)(mN) | F(100-)(mN) | |
| 3# | 6 | 11.5 | 10.83 |
| 4# | 31 | 52 | 7.79 |
| 5# | 8 | 23 | 9.55 |

F(0+): Initial debonding

F (100-): Completed debonding

IMF: Interfacial Microdebonding Force between single z-D fiber and matrix

DS: Debonding Strength of z-D fiber bundles

Table 2. Interfacial properties of z-D fiber bundles and relative macroscopic properties

| No. | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| ISS(MPa) | 8.89 | 8.74 | 8.66 | 7.97 | 8.08 |
| TS(MPa) | 1 | 1.06 | 1.11 | 1.13 | 1.17 |

ISS: Interfacial shear strength

TS: Tensile strength relative value in z-D fiber bundles