# POSTER

## MECHANICAL BEHAVIOR OF CARBON/CARBON COMPOSITES

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### INTRODUCTION

The carbon fiber / carbon matrix composites (c/c) are now being used in many systems such as rocket nozzle, reentry shield of space vehicles, disk brake and heating element, because of its excellent ablation resistivity and thermal properties [1].

However, it is a focus problem to develop c/c to become a kind of high temperature structure material. The study of various mechanical behaviors of c/c is significant to its application and development.

In this paper, the tensile strength, bend strength, high temperature endurance strength of c/c are tested and compared with traditional materials such as metal and graphite.

### EXPERIMENT

The specimens for the tensile strength and bend strength test are the tetra-axial c/c composites which are cut from aeroengine brake and then reshaped. The density of this material is 1.77 g/cm$^3$.

The tensile strength test is completed on the MTS Electronic Testing Machine. Loading strength, deformation and displacement of clamping head are in-situ detected by PC486. Loading rate is 0.5 mm/min. The bend strength test is completed on CSS-1110 Electronic Versatile Test Machine.

The specimen for the high temperature endurance strength (HTES) test are self-made unidirectional c/c composites. Experiment is completed on the apparatus designed especially for HTES test [2].

### RESULTS AND DISCUSSION

The result of tensile test is profiled as figure 1. This profile is somehow similar to the tensile profile of plastic metallic materials. The profile is linear at the initial loading stage. When the loading strength is over a certain value, the profile begins to bend. Crack appears on the surface of specimen as the loading strength reaches the peak. After that, instead of dropping abruptly like fragile materials, loading strength still keeps higher value. The deformation is noticeable during the whole tensile process. It is observed that the fiber in parallel direction are slowly pulled out from the crack.

However, this pseudo-plasticity of c/c composites is intrinsically different from the plasticity of metal. For c/c composites, there are not five independent slip bands which are required for plastic deformation by multicrystal materials. Furthermore, the multi-directional reinforced fibre and its multi-interface in c/c make it hard to deform through slip. The deformation is mainly carried out by the change of porosity and the fibre's being pulled out. The porosity in c/c composites is easy to be magnified under tensile stress and new crack will be generated to relieve the internal stress since c/c lacks slip band. Compared with fibre and matrix, interface has the lowest strength [2]. Therefore, interface will break up first under stress. The macro deformation appears as fibre being consecutively pulled out from matrix.

The forming and spreading of one crack in graphite will result in its ultimate breaking. But c/c is distinguished for its non-uniformity and structural complexity. The strength of fibre is much higher than that of matrix and interface.The forming and spreading of initial crack does not mean its rapid breaking. When the crack meets the interface between the fibre and matrix, generally it is the interface that practices first. This changes the orientation of crack and makes it spread along the interface. The tensile process, from the forming of crack to the ultimate breaking of specimen, is accompanied by a series of complex processes including crack's orientation changing, crack's spreading along the interface , fibre's detaching from matrix and finally fibre's being pulled out. Therefore, unlike graphite's breaking abruptly, c/c composites will have a series of follow-up cracking as loading increases.

In general, c/c composites is characterized for its excellent toughness. It has been demonstrated experimentally that c/c plate did not break even a nail was driven into it.

The profile of bend test result is shown as figure 2 , which demonstrates the pseudo- plasticity and larger bend-break energy of c/c. In addition, the curve appears non-smoothed and saw-tooth shape. Every segment of saw-tooth, such as AB and CD, can be

extrapolated to near the origin point, which coincides with the theory [3].

While being bent, the midpoint of lower surface is imposed with the largest tensile stress and break up first. The fibre in parallel direction are detached from matrix first and strength decrease. However, because there are many interface within specimen, cracks keep changing orientation and deforming consecutively. Therefore the residue of specimen still bear the load and the curve still has the rising trend. After several cycles, the curve appears saw-tooth like.

The results from HTES test show that the HTES of c/c increases with temperature. The specimen endures 8 kg loading for 8 hours at 2300°C while only 4 hours at room temperature. This exceptional property will be significant for the high temperature structure application of c/c composites.

## CONCLUSIONS

1. Compared with graphite materials, c/c composites are distinguished for their nonbrittleness and better plasticity.

2. The non-brittleness of c/c is intrinsically different from the plasticity of traditional metal.

3. Instead of the slip and twin dislocation mechanism, the plastic deformation of c/c is caused by the change of inner porosity and the detaching of fibre and matrix.

4. The high temperature endurance strength of c/c increases with temperature.

## REFERENCES


1. Richard A. Wagner, Babcock & Wilcox, Lynchburg, "A Novel Impregnation Process: Application to Carbon/ Carbon Composites", *Ceram. Eng. Sci. Proc.*, 9, 958 (1988).
2. Qiuyan Zhao (1994), BS Thesis, Northwestern Polytechnical University
3. S.Y.Zhang (1993), " Mechnical Properties of Composites Structure", Beijing Science and Technology University Press.


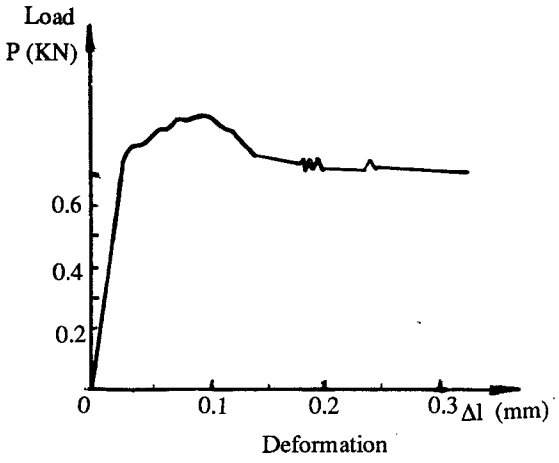


Figure 1 Profile of Tensile Test of c/c

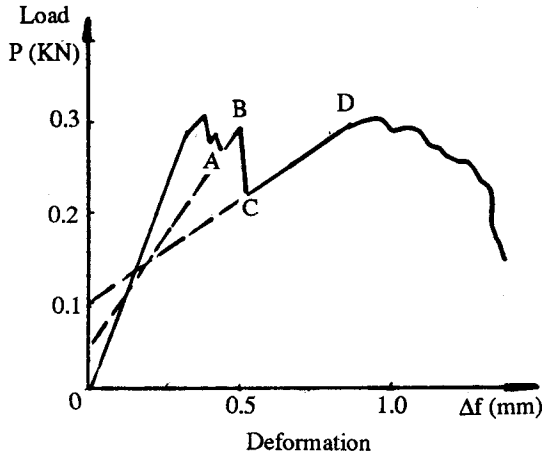


Figure 2 Profile of Bend Test of c/c