FRACTURE BEHAVIOR OF CARBON FIBER-GLASSY CARBON COMPOSITE

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Introduction

The mechanical properties of carbon fiber-carbon composite are considered to be strongly dependent on material structure, ie., matrix, fiber or interface[1]. The fracture behavior of carbon fiber-glassy carbon composite was investigated and discussed in relation to the microstructure.

It was reported previously that the glassy carbon was graphitized to layer structure in the composite at about 2400 °C. The graphitization starts at the fiber-matrix interface and proceeds into the matrix[2]. The graphitic layer structure aligns its layers parallel to the fiber axis. The graphitization seems to be accelerated by the stress accumulated around fibers when the resin matrix shrinks by 47 wt% during carbonization.

In this study, it is found that the increase of strength accompanied the pseud-plastic fracture manner is measured by the graphitization of the matrix.

Experimental procedure

Unidirectionally reinforced composite were prepared by filament winding technique, using furfuryl alcohol condensate as matrix carbon precursor. Commercially available PAN based carbon fiber yarns (Torayca T200, Toray Industries, Inc.,) were employed. The strength and the young's modulus of the fibers are about 200 kg/mm^2 and 20×10^3 kg/mm^2 respectively.

Carbonization temperature was 1000 °C and graphitization was carried out up to 2800°C. The fiber content is about 50 vol% after carbonization treatment.

The testing bars were cut into $60\times10\times3$ mm orientating fibers parallel to longitudinal direction. The notch (0.25 mm width and 1 mm depth) was machined by a diamond blade.

The strength was determined by four point bending test with constant loading velocity. The dynamic young's modulus was calculated from the measurement of ultrasonic velocity.

Results and discussion

(1) Young's modulus

Fig.1 shows the dynamic young's moduli in the longitudinal (fiber) direction and the transverse (perpendicular to fiber axis) direction.

The longitudinal young's modulus increased from about 9 to 17×10^3 kg/mm^2 by the heat treatment. This modulus seems to be determined by the high modulus of PAN based carbon fiber, since fibers are continuous through the specimen in this direction.

The transverse young's modulus was in the range of $0.2\sim0.4\times10^3$ kg/mm^2. It inclined to reduce by the heat treatment. In the transverse direction, the young's modulus should be a reflection of low modulus carbon matrix. The pores induced in the matrix increasingly by the heat treatment might contribute to reduce the young's modulus.

(2) Strength

The structural change of matrix was influencing the strength and the fracture behavior.

Fig.2 shows that the strength increases by the increase of heat treatment temperature. The strength was calculated from a maximum load of bending test.

Typical load-deflection curves for specimens heat treated at temperature of $1000°\sim2800$°C are shown in Fig.3. Specimen carbonized alone shows an elastic failure.

Carbonized composite (H.T.T. 1000°C) consists of carbon fiber and glassy carbon matrix. This composite was broken in a brittle manner, and gave relatively low strength of about 10 kg/mm^2 . Scanning electron microscopy has revealed the smooth fracture surfaces which opened perpendicular to fiber axis (Fig.4a). The fiber pull-out was not observed. The crack seems to propagate matrix crossing fibers in one direction. The reinforcement of fibers may not appear in the brittle fracture manner.

Fig.4b shows the fracture surface of the composite heat treated at 2800°C. The matrix has changed to graphitic layer structure. The fracture surface revealed a fibrous one with fiber pull-out. The crack did not propagate colinear to the machined notch, rather, but to the relatively weak interfaces between fibers and matrix by a delamination process. The delamination blunts the crack and absorbs energy. In fact, the load-deflection curve deviated from the linear relation.

The anisotropic layer structure of matrix prevents the crack propagation, and results in high strength and large energy for failure.

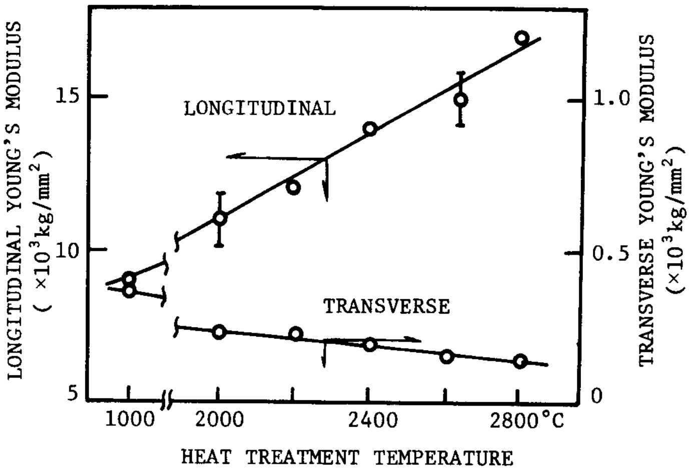


Fig.1 Dynamic young's modulus.

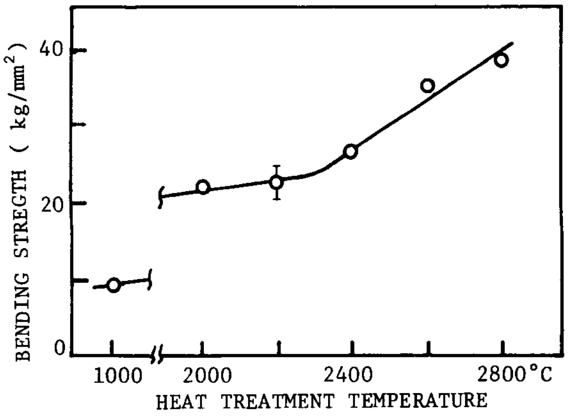


Fig.2 Strength of the composite.

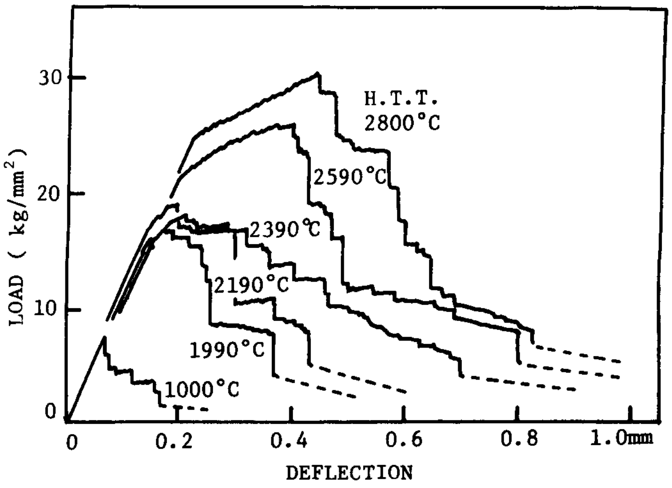
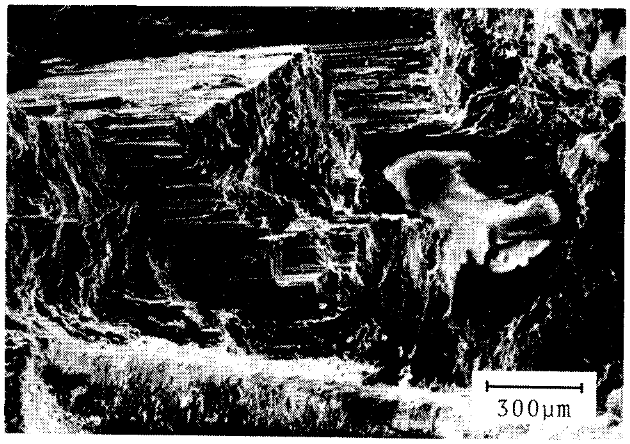


Fig.3 Fracture behavior on the four point bending test.

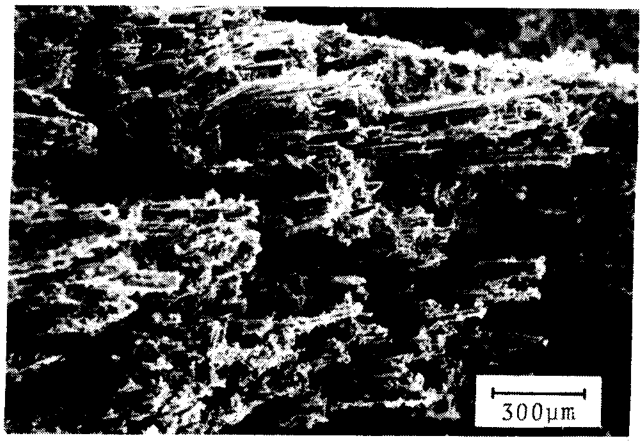
References

1) L.Boyne, D.Cook, J.Hill and K.Turner, SCI 4th London International Carbon and Graphite Conference, (1974) p50.
T.R.Guess and W.R.Hoover, J. Composite Materials, 7,2 (1973).

2) Y.Hishiyama, M.Inagaki, S.Kimura and S.Yamada, Carbon, 12, 249 (1974).
S.Kimura, E.Yasuda, H.Tanaka and Y.Yamada, J. Ceram. Soc. Japan, 83, 122(1975).



a) H.T.T. 1000°C



b) H.T.T. 2800°C

Fig.4 Fracture surface of carbon fiber-glassy carbon composite.