# Graphite-toughened Carbon Matrix Composites.

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## Introduction

Carbon materials find varied applications where mechanical properties are important. Fine- grained monolithic carbon is often limited by brittle mechanical behaviour, flaw sensitivity, variability in properties.

When mesophase powder is compacted and carbonised it is found that the particles are directly bonded giving materials which can have high strength. Carbon products with bending strengths as high as 150 MPa have been produced[1] and further improvements are likely. This improvement in strength is at the expense of the fracture toughness and thermal shock resistance. An important factor contributing to the fracture toughness of the polygranular carbon materials is the lamellar domain type of microstructure and the presence of disclinations within this structure.[4]

One possible method of increasing the toughness and hence the reliability and thermal shock resistance of brittle materials is to incorporate weak interfaces into the material which act to deflect propagating cracks. Natural platelet graphite is a possible agent that could impart that characteristic behaviour to a brittle carbon matrix. A weak interface may arise from two effects. The low energy basal plane does not easily bond to other phases. The high c-axis thermal expansion coefficient lead to large tensile stresses perpendicular to the basal planes on cooling from the carbonization temperatures which may result in debonding.

Brooks and Taylor [2-3] first reported that the mesophase formed from coal-tar pitch wets graphite and mica flakes and that the mesophase layers tend to align parallel to the layer planes of these substrate materials. In this work natural graphite platelets have been used to produce carbon matrix composites with a toughness increased over that of the matrix alone. Mesophase microbeads have been used as a matrix. The Volume percent and size of the graphite platelets have been varied in order to study the effects of these parameters on the mechanical and thermal properties. However, only, mechanical properties will be discussed in this paper.

## Experimental

The composites were prepared using Kawasaki mesophase powder and very pure natural platelet graphites as a reinforcement. The powders were mixed together in the dry state and then passed through a 500 micron sieve. Some physical properties of the powders are shown in table 1. The sieved powders, which contain 5-15 %vol. graphite platelets, were pressed in a steel die under 140 MPa. The green pressed, disc-shaped composites were heat treated slowly under an inert atmosphere up to 1500°C. X-ray pole figures were used to identify the orientation of the graphite platelets. Flexural strength and modulus were measured at room temperature by three-point bending with a 20 mm span. Apparent work of fracture was calculated from the cross sectional area of the bar and the area under the load deflection curve.

## Results

Incorporation of natural graphite platelets in the mesophase matrix caused the fracture behaviour of this kind of carbon composite to change from nearly catastrophic to non-catastrophic for medium and large size graphite platelet-containing composites. A typical load-deflection curve of this composite, together with that of the pure mesophase sample is shown in fig. 1. With fine size graphite platelets brittle fracture behaviour is retained.

Although the toughness of some composites is increased this is accompanied by a progressive decrease in both flexural strength and modulus with increasing graphite size and content(fig. 2).

The Weibull modulus (m) of the matrix alone and the composites have been determined by using 20-25 fracture measurements of the composites. A considerable increase in m has been obtained for medium and fine size graphite platelets, and the values were about 2-3 times that of the matrix which was about 10.

## Discussion

Incorporation of graphite platelets into the mesophase could lead to the fabrication of a new kind of CC . The bending strength of these sort of CCs are lower than the matrix alone. This is mainly because of the presence of nearly vertically aligned platelets at the surface of the composites. Evidence for the orientation of the platelets is given by the pole figure technique. A microstructure study of the fracture surface of the composites supports the pole figure analysis. However, multiple fracture and higher work of fracture could be obtained depending on the size, volume content and orientation of the graphite platelets. The increase in the toughness of some of the composites may be due to energy dissipation mechanisms such as crack deflection, pull out , directional induced cracks, all caused by the presence of graphite platelets in composites. The reliability of the composites in terms of Weibull modulus has been increased because the defect population is effectively controlled by the platelets.

## Conclusion

Graphite platelet-containing carbon composites (GPCCC) are a new kind of CC in which the incorporation of graphite has the effect of increasing toughness for specific size distributions and volume contents of graphite. The reliability of GPCCC in terms of Weibull modulus could be much higher than the matrix alone. Orientation of platelets in the bulk of the composite has a considerable effect on decreasing the strength as well as controlling fracture behaviour.

## References:


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Table 1. Some physical properties of materials used for fabrication of the composites.

| | Density g.cm$^{-3}$ | $d_{90}$ μm |
|---|---|---|
| mesophase microbeads | 1.42 | 22 |
| Graphite (fine) | 2.26 | 53 |
| " (medium) | 2.26 | 375 |
| " (Large) | 2.26 | 504 |

Table 2. Some values of work of fracture (w.o.f.) and Weibull mudulus of the fabricated composites.

| | matrix | medium | coarse |
|---|---|---|---|
| w.o.f J/m$^2$ | 68 | 170 | 195 |
| m | 10 | 23 | 20 |
| graphite vol.% | 0 | 10 | 10 |

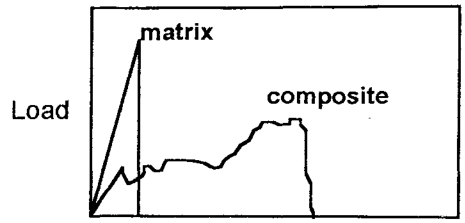


Fig. 1 Schematic representation of load-deflection curves of the composite and matrix.

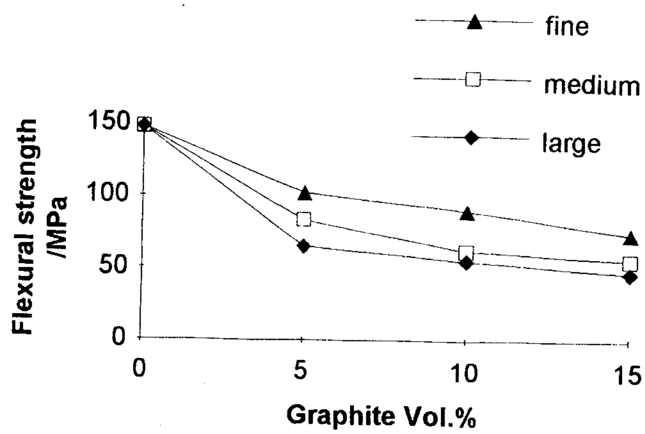


Fig.2 The effect of graphite size and content on flexural strength.


## Acknowledgements

To Iranian Government for financial support, and to Kawasaki Steel and Mr. K. Nagayama for supply of microbeads, also to Magnesita SA and Mr. W. Vieira, and Rocol company for graphite supply.