The Characterization of Carbon-Carbon Composite Materials

B. A. Ford, R. G. Cooke, B. Harris.
School of Materials Science
University of Bath
BATH, BA2 7AY,
U.K.

Introduction

It is difficult to model the behaviour of carbon-carbon composites using standard composite theory or with classical brittle fracture models. However, carbon-carbon has many potential uses in the aero-space and related industries, so there is a need to understand their behaviour thoroughly.

The term 'carbon-carbon composite' covers a very large range of materials, so it is necessary to study the behaviour of several different systems before attempting to select models. This paper reports work done at Bath University on 2D woven fabric laminates. (1)

The experimental program consisted of the following:-

a) The determination of densities (ρ), porosities (π) and fibre volume fractions (V_f)

b) Optical microscopy of polished sections using polarised light and sensitive tint methods also electron microscopy of etched surfaces. (2)

c) The measurement of mechanical properties; sonic resonance was used for modulus determination, flexural testing for strength measurements, and single edge notched testing for fracture toughness determination. Acoustic emission was monitoring during mechanical testing.

d) Electron microscopy of fracture surfaces.

Results

Data have been obtained for two materials. Material 1 was based on a square weave cloth of rayon fibres. Material 2 was a balanced 8 harness satin weave of PAN fibres. The outer plies are woven at 0/90^o and the inner plies at ± 45^o. The properties of these materials are shown below:

Material		ρ (gcm^{-3})	π (%)	V_f (%)	ρ_f (MPa)	E (GPa)	ε_f (%)	K_{IC} (MPa $\sqrt{m}$)
1	warp				128	40	0.3	4.7
	fill	1.5	16	25	55	19	0.3	2.7
2		1.7	12	40	280	160	0.2	13

Load-deflection curves are shown in figures 1 and 2.

Discussion

Low density material

The properties are different in the two weave directions. Microscopy showed that in the fill (weak) direction the fibre bundles are loosely packed, but in the warp (strong) direction they are tightly packed and there are fewer matrix rich regions. The material is also seen to contain many large elongated pores, which are due to matrix shrinkage. There is also a fine network

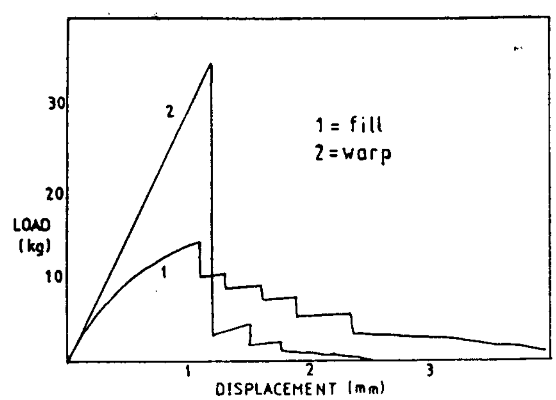

Fig. 1. Load-deflection curves for square weave laminate.

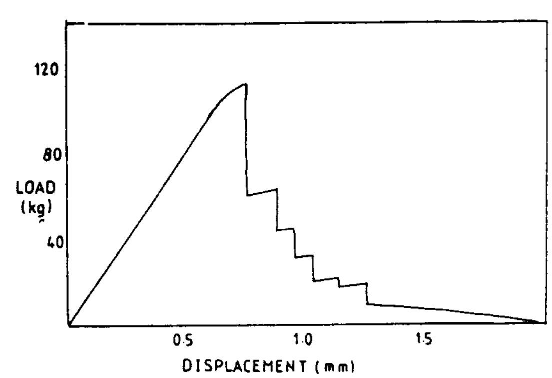

Fig. 2. Load-deflection curve for a satin weave laminate.

of microcracks between fibres. The progress of cracks was monitored in specimens tested by three point bending. It was seen that in the warp direction failure was catastrophic and there was little sign of crack arrest. In the fill direction, however, the crack advanced in a controlled manner by linking up large pores. (fig.3). There is a lot of subcritical crack opening activity ahead of the main crack front.

Examination of the fracture surfaces showed that the fibres broke only after most of the matrix had disintegrated around them.

High density material

The nature of the satin weave means that the microstructure, and hence the properties are the same in both directions. There are large matrix shrinkage cracks present, but very little porosity on a smaller scale.(fig.4). It was seen that each fibre is surrounded by a sheath of matrix material in which the graphite basal planes are parallel to the fibre surface. There seems to be a good bond between fibre and matrix i.e. no gap was seen between them.

Observation showed that the high fracture toughness was due to delamination ahead of the crack front. Once again, the large pores were the means by which the crack crossed the fibre bundles. Clearly, this material behaves more like a conventional laminate than a simple brittle material.

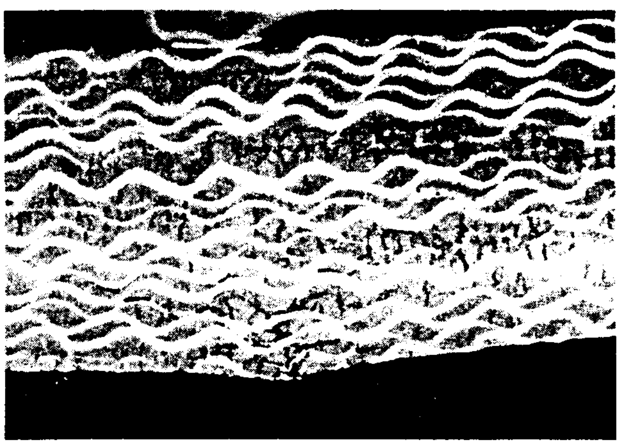

Fig. 3. Controlled crack propagation in a square weave laminate.

Fig. 4. Matrix shrinkage cracks in a satin weave laminate.

Conclusion

These observations illustrate the difficulties in using the standard models on carbon-carbon composites. Clearly, an amalgam of composite theory and porous brittle theory is needed to explain fully the mechanical behaviour. Any model must take into account the interation of pores and cracks in a process zone ahead of a growing crack. Work is continuing to this end.

References

1. Ishikawa & Chou, J.Mat.Sci. 17 321-322 (1982).

2. Forrest & Marsh, J.Mat.Sci. 18 973-977 (1983)

Acknowledgements

The collaboration of Rolls Royce Ltd., in this project is gratefully acknowledged, also the SERC for financial support.