ON THE RELIABILITY OF GRAPHITE PLATELETS COMPOSITES.

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Introduction

Ideally, the strength variations in brittle materials should be related to the variables in the Griffith equation, and when the crack size is related to the grain size, the variation in strength should be related to the distribution in sizes of the largest grains.

Due to the anisotropy in thermal expansion graphite flakes within a composite can be the origin of flaws[2-3]. In previous papers[1-3] it was shown that the presence of graphite flakes in fine matrices can increase the toughness and reliability of the composites at the expense of strength. Here a model is presented to correlate the strength variability of the materials with flaw sizes which shows that high values of Weibull moduli materials are unlikely with high strength.

Experimental

Two series of graphite flake composites were prepared, as described previously[1-2] with carbon and alumina matrices from Kawasaki KMFC mesophase microbead powder and Alcoa A16 powder respectively. Three size fractions of graphite flakes were used with sizes less than about 53μm (fine), 277 μm (medium) and 504 μm (large).

Flexural strength was measured on samples 25×3×3 mm. using the three-point bending technique with a 20 mm span. The Weibull moduli (m) of the matrix alone and the composites were calculated from 20-25 fracture measurements.

Results & Discussion

The graphite platelets in the fine grain matrices decrease the strength (eg. Figs.1). Increasing the size and volume content of graphite decreases the strength considerably at 5 Vol.% but, from 5 to 15 Vol.% the decrease in strength is not very pronounced especially for the larger size graphites.

The Weibull modulus increases mainly because of the plate-like cracks associated with the flakes. Thus, the strength controlling cracks have been incorporated in the matrix in advance. As a consequence, fracture should occur closer to the stress that the Griffith's equation predicts when the crack size is identified with the long flake dimension. The closer the strength is to the Griffith's value, the less variability in strength that must exist. In other words a greater Weibull modulus is expected. Table 1 shows that the Weibull modulus increases up to 5 Vol. % graphite and then decreases. It also increases with flake size (Table 2). The decrease can be by the interaction of the flakes when their population is higher than a specific value.

The Griffith's equation predicts the variation of σ_f with C (crack length), shown in Fig. 2 for various K_{IC} values. There is a steep curvature as $C \rightarrow 0$. In practice, there is a distribution of crack sizes and hence a corresponding strength distribution for a material with constant K_{IC}. Assuming that the distributions of σ_f and C follow normal distributions, graphs such as those in Fig.3 can be obtained. Taking two ranges of C of same magnitude but with different means, the corresponding strength ranges will be quite different: $\Delta\sigma 1 > \Delta\sigma 2$. This means that a larger scatter in strength should be expected for stronger materials even with a narrow crack distribution. This is true for the reverse situation, i.e., with a similar distribution of strengths the weaker materials can have a wider distribution of crack lengths.

Fig.2 clearly shows this concept by comparing Griffith's equation derivatives for different values of K_{IC} and constant Y = 1.12.

$$A = K_{IC}/Y \quad d\sigma_f / dC = -A/ (2\sqrt{C^3})$$

For small crack sizes the strength variation with increasing size is dramatic but the derivatives show that at large sizes the variation is minimal. This is what was observed. The strengths of composites with medium and coarse flakes are similar and the strength variation at large graphite contents (when cracks interact) is also small.

As can be predicted from load-deflection curves of some of the fabricated composites[1-2], R-curve behaviour may be expected. As a result, order of magnitude increases in m are predicted[4]. Therefore, either considering the proposed simple model in this work (Fig.3) or the above explanation for materials with R-curve behaviour will lead to higher values for Weibull modulus.

Conclusion

Graphite platelet-containing composites are new composites with much higher reliability than the matrix alone. The above discussion shows that:

Materials with higher strength are more likely to have a wider scattering in strength, as is well known for high strength metals and alloys. Therefore, a lower Weibull modulus is common for higher strength materials and rigorous process control is needed to control flaw sizes if higher moduli are required.

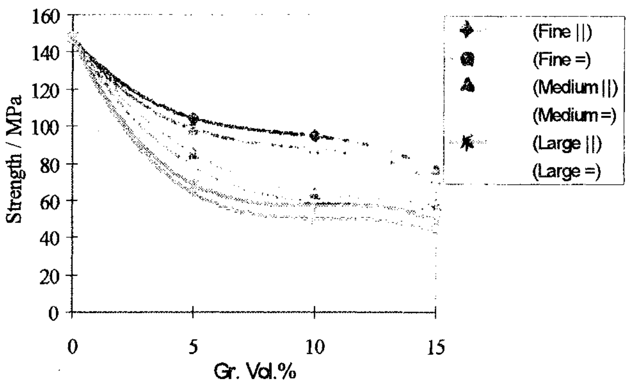

Fig.1 Flexural strength as a function of graphite content for the carbon matrix composites.

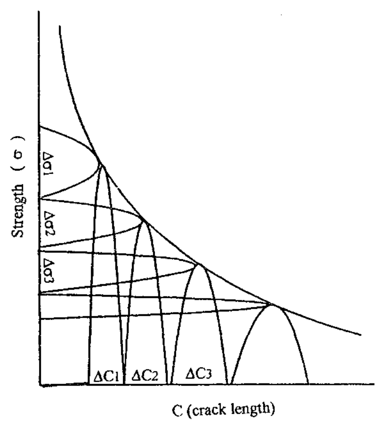

Fig.3 A proposed model to correlate strength scattering in terms of the Weibull modulus to the Griffith equation (σ-c), for a constant K_{IC}. Crack size may be replaced by graphite flake size.

References:

1. Mirhabibi & Rand, B., Extended abstracts of 22nd Biennial Conference on Carbon, pp.192-193, 1995.
2. Mirhabibi, Rand, B.,& Hind D., Extended abstracts of 22nd Biennial Conference on Carbon, pp. 96-97, 1995.
3. Mirhabibi & Rand, B. Extended abstracts of "Carbon 96", pp. 142-143.
4. Cook, R. F., et al., J. Am. Ceram, Soc., 68, 604-15.

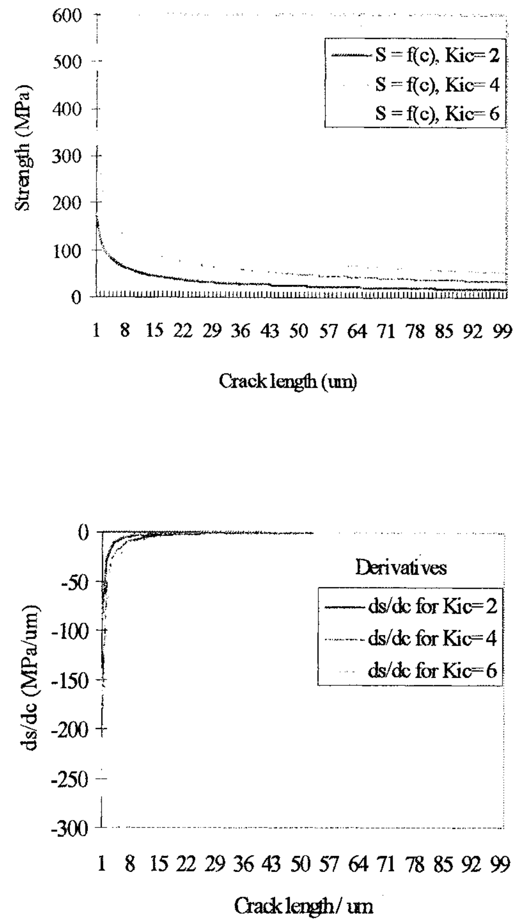

Fig.2 A graphical representation of Griffith's equation and the derivatives for different values of K_{IC} and constant Y (s = σ_f).

Table 1 Weibull moduli of the medium size graphite flake CC composites.

Gr. Vol.%	0	5	10	15
m	9.8	30.3	23	7

Table 2 Weibull moduli of the graphite alumina matrix composites.

Gr. Vol. %	d90 (< μm)	m
0	4 (matrix)	5.8
5	277 (medium size)	17
10	53 (fine size)	11.5
10	277 (medium size)	19
10	504 (large size)	20.8
15	277 (medium size)	16

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