X-RAY DIFFRACTION STUDIES OF WEAR DEBRIS FROM CARBON - CARBON COMPOSITE AIRCRAFT BRAKES.

Toby J Hutton and Brian McEnaney.

School of Materials Science, University of Bath, Bath BA2 7AY, UK.

INTRODUCTION

Carbon-carbon composite aircraft brakes were initially developed in response to demand from the aircraft industry for light brakes for supersonic and vertical take off aircraft [1]. Although such brakes have been used increasingly for over twenty years, the mechanisms of wear are still not firmly established. A general wear mechanism has been proposed [2] in which abraded wear debris is deformed into a friction film that adheres to the wear surface. The friction film eventually delaminates, and then is abraded and recycled into another friction film. This is an imperfect process and some wear debris escapes from the brake. Very little is known either about the microstructural changes to the carbon friction materials during abrasion, friction film formation, delamination and repair, or about the influence of the various aircraft braking operations upon these processes. This paper reports an X-ray diffraction study of wear debris obtained from carbon-carbon composite aircraft brakes subject to test cycles that simulate various aircraft braking operations.

EXPERIMENTAL

An inertial dynamometer connected to a configuration of three aircraft disc brakes (one rotor and two stators) was used to produce samples of wear debris under simulated aircraft braking conditions. The brake material was a carbon-carbon composite utilising PAN based carbon fibres and a CVD carbon matrix. The dynamometer test programmes were designed to simulate 50 cold taxi cycles and 50 landing cycles. A larger dynamometer connected to a full-size aircraft brake was used to produce wear debris from a simulated rejected take off. The resulting wear debris was collected from beneath the brake and analysed without any pre-treatment using a Phillips PW1710 X-ray diffractometer. The spectra were corrected for machine line broadening as well as Lorentz, polarisation and dispersion effects. The curves were then analysed to obtain values of $d_{(002)}$, L_a, and L_c. Values of L_a and L_c are sensitive to lattice imperfections which decreases the observed crystallite size, however, these parameters provide an excellent base on which to compare the wear debris samples.

RESULTS AND DISCUSSION

X-ray spectra for the carbon-carbon composite (a), and for wear debris collected after 50 cold taxi cycles (b), landing cycles (c) and rejected take off (d) are shown in Figure 1 (a)-(d) respectively. Values of interlayer spacing and crystallite size for the same samples are in Table 1 . As expected from a carbon-carbon composite with a CVD matrix, the parent material has a structure which is quite graphitic, with an average interlayer spacing of 3.38 Å and average crystallite sizes (L_a and L_c) of approximately 200 Å. Figure 1(b) shows that as a result of 50 simulated cold taxi cycles the graphitic order that was present in the base composite was almost completely destroyed in the wear debris, as indicated by the interlayer spacing which increased to 3.43 Å and the values of L_a and L_c which were reduced to 34 Å and 64 Å respectively, Table 1. The extent of disruption of the graphitic order in the base composite was of a similar order to that reported in a recent study of the effects of grinding upon the structure of a natural graphite [3]. Wear under cold taxi conditions is thought to result from abrasion at the wear surface which disrupts the graphitic structure of the parent composite and produces wear debris on a very fine scale (extending to < 0.1μm). The low power density and wear surface temperature associated with the cold taxiing (180 kWm^{-2} of interface and ~ 100°C) limit the ability of the wear debris to deform plastically and produce a friction film, resulting in high rates of wear.

The X-ray spectrum for wear debris obtained after 50 simulated landings, Figure 1(c), contains a sharp graphitic peak and an amorphous halo at the 2θ value associated with the (002) interlayer spacing, indicating the presence of two components in this material. Deconvolution of the peaks enabled the L_c value of the ordered component to be determined; the L_a value could not be determined as it is obscured by the broad peak at 2θ ~ 42°. The Lc value suggests that the ordered component has a graphitic character that is similar to that of the parent composite. This may indicate that the wear debris obtained after simulated landing conditionscontains fragments that retain elements of the microstructure of the base composite. The disordered component has a degree of graphitic disorder that is comparable to that produced after the simulated cold taxi cycles. The composite brake is known to exhibit lower wear rates under landing conditions than under cold taxi conditions.

The X-ray spectrum for the wear debris obtained after a simulated rejected take off, Figure 1(d), indicates the presence of a single component in which the degree of graphitic order is greater than that for the wear debris obtained after simulated cold taxiing, but not as great as the parent material, Table 1.

A rejected take off is the most severe braking condition with a power density of 1.5-2 MWm^{-2} and an interface temperature in excess of 2000°C [4]. These high interface temperatures, together with the high shear forces will produce conditions favourable for shear-stress assisted graphitisation.

CONCLUSIONS

The wear debris produced from carbon-carbon composite aircraft brakes after simulated cold taxiing is more highly disordered than the parent composite. After simulated landing cycles, wear debris containing an ordered and a disordered component is found. The structure of the disordered component is similar to that found after cold taxiing, while that of the ordered component is similar to the parent composite. Wear debris found after a simulated rejected take off is more ordered than that found after cold taxiing. This ordering is attributed to stress graphitisation at the wear surface as a result of the high surface temperature and shear stresses.

ACKNOWLEDGEMENTS

The authors would like to thank the EPSRC and the Aviation Division at Dunlop Ltd. for their financial support.

REFERENCES

1. I.L. Stimson and R. Fisher, Phil. Trans. Roy. Soc., Lond., A294, 583 (1980).
2. N. Murdie, and P.U. Ju, Carbon 29(3) 335, (1991).
3. J.B. Aladekomo and R.H. Bragg, Carbon 28(6), 897, (1990)
4. S. Awasthi, J.L. Wood, Advanced Ceramic Materials 3(5), 449, (1988).

Table 1: Table of interlayer spacings and crystallite sizes for the base composite and wear debris samples.

Material	d(002) / Å	La / Å	Lc / Å
Base Composite	3.38	200	200
Cold Taxi Wear Debris	3.43	34	64
Landing Wear Debris a	3.38	-	200
Landing Wear Debris b	-	37	10
Rejected Take Off Debris	3.39	150	65

a: ordered component; b: disordered component

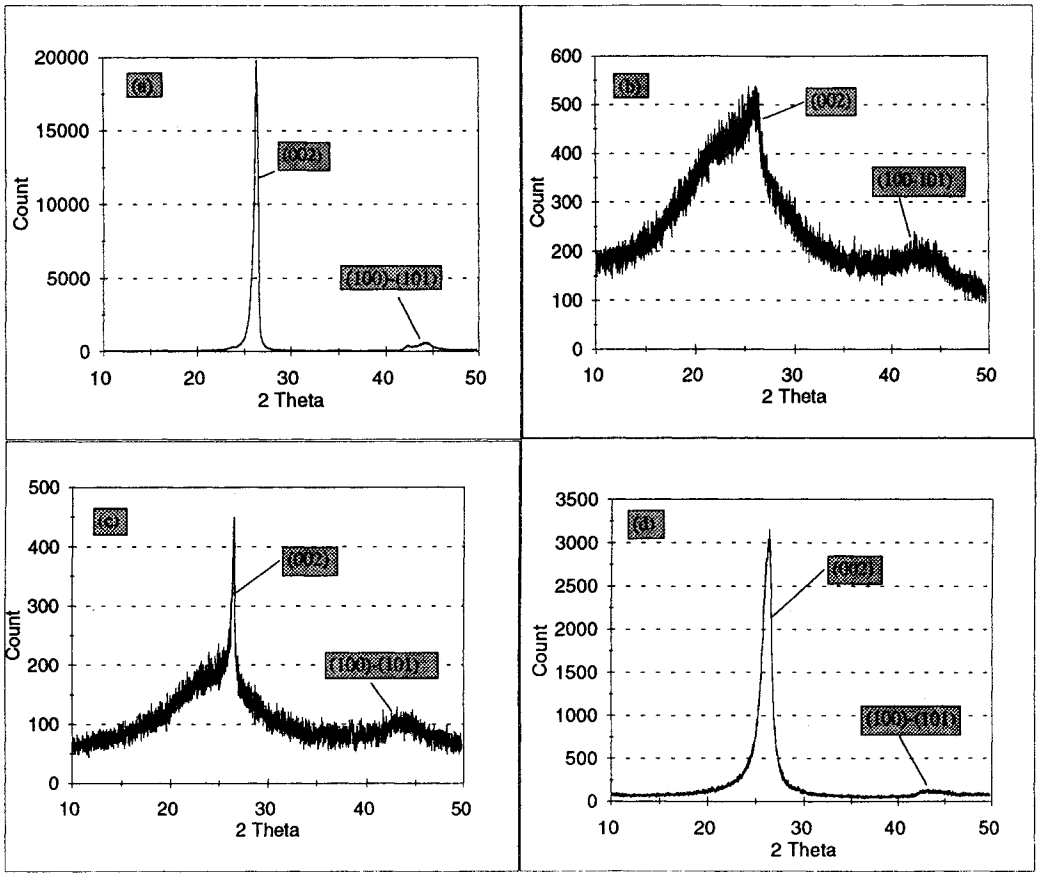

Figure1: X-ray spectra for the base composite (a), cold taxi debris(b), landing debris (c), and rejected take off debris(d)