THE FATIGUE BEHAVIOR OF THIN CARBON FILMS

H.S. SHIM, N.K. AGARWAL, A.D. HAUBOLD
General Atomic Company
P.O. Box 81608
San Diego, California 92138

Composites made of vapor-deposited thin carbon film and appropriate substrate material (e.g., metals) are being considered for use in prosthetic devices such as artificial heart valve housings, fracture fixation plates and dental implants. A few of the most important properties required for these devices would be that the carbon films are structurally similar to LTI carbons* which are highly biocompatible, adequately adhere to the substrate, and do not undergo dynamic fatigue failure. The strucutre of the vapor-deposited carbon films and its bond strength to the metallic substrates have been characterized[1,2]. In this presentation, the fatigue behavior of thin carbon film on stainless steel (Type 304) is discussed.

Carbon film of about 4000-5000Å was deposited on tensile coupons cut from highly polished stainless steel sheet (0.005-inch thick). The composites were then uniaxially flexed with a cyclic rate of 60 cpm and various strain levels. During the test, carbon film surface was periodically monitored with a microscope and, at the end of each test, the final surface topography was examined in detail using a scanning electron microscope.

The results are summarized in Fig. 1. The calculation of film stress requires a knowledge of Young's modulus, which is very difficult to measure. The results are therefore expressed in terms of strain versus number of cycles to failure rather than stress versus number of cycles to failure.

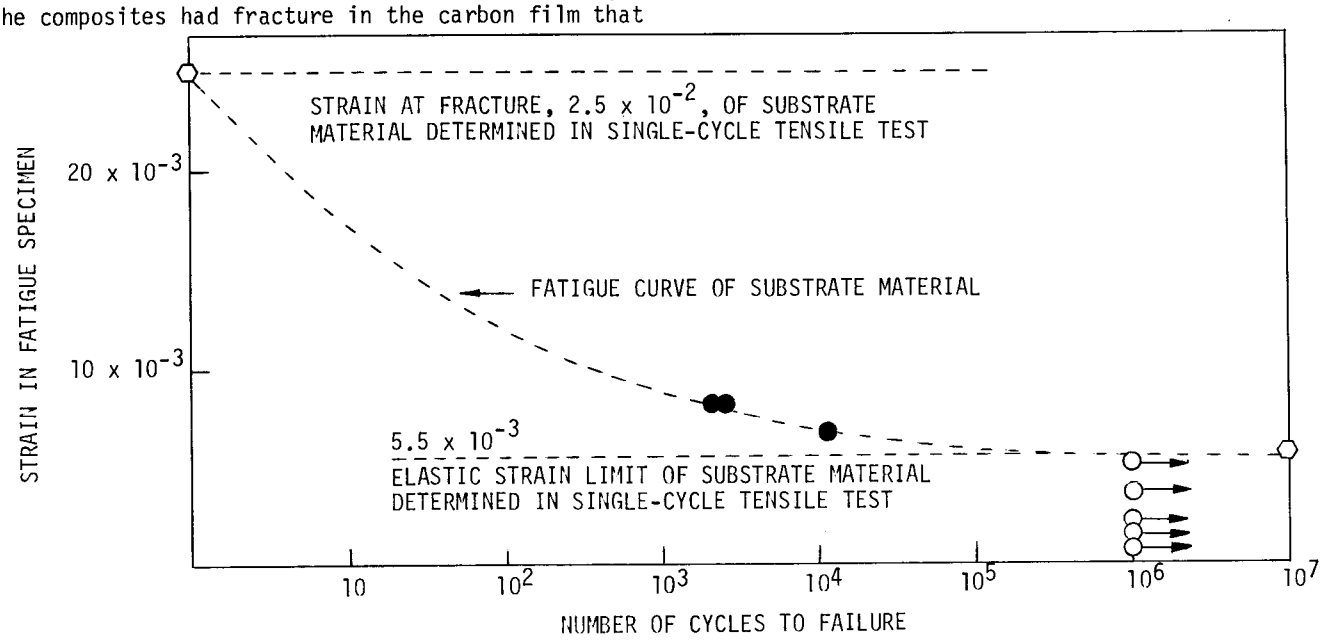
It was found that the carbon film in composites would not fail if flexed below the elastic strain limit of the substrate. Above this strain level, the composites had fracture in the carbon film that always coincided with the onset of plastic deformation in the substrate. In other words, the carbon film fractured only and if the substrate has plastically deformed, and no carbon film failed first in fatigue before the substrate failed; i.e., the carbon films, like LTI carbons, are immune to dynamic fatigue. The strains at the elastic limit and the fracture were measured in independent tensile testing, and were 5.5×10^{-3} and 2.5×10^{-2}, respectively.

In conclusion, the carbon film in prostheses would remain as a protective coating so long as the metallic substrate in function flexes within its elastic strain limit. If exceeded, the prostheses would become inserviceable, not because of the carbon film fracture but because of the configurational distortion in the prostheses. Currently, the tests are being continued using carbon film/polymer composites.

This work was supported in part by NHLI (S.D. Bruck, Program Manager).

* Commercially availalbe under a registered trade name of Pyrolite[R] Carbons.

References

(1) H.Shim, N. Agarwal, A. Haubold, "The Microstructure of Vapor Deposited Carbon Films", This Conference.

(2) N. Agarwal, H. Shim, A. Haubold, "The Adhesion of Thin Vacuum Deposited Carbon Films", This Conference.