DYNAMIC MECHANICAL PROPERTIES OF GRAPHITE*

R. E. Taylor+, D. E. Kline, and P. L. Walker, Jr.

Pennsylvania State University

The measurement and interpretation of the internal friction and dynamic moduli of polycrystalline and pyrolytic graphites and glassy carbons has been reported by Tsuzuku and Saito[1]. Their primary interest was the amplitude dependence of the internal friction and dynamic moduli of these materials. However, a study of the amplitude independent behavior over a large temperature range is also helpful in determining and understanding the behavior of graphites, including radiation effects. Consequently, the dynamic moduli and internal frictions of pitch-bonded natural graphite crystals, pyrolytic carbon, stress-annealed pyrolytic graphite, vitreous carbon, and a variety of commercial graphites were measured from 4° to 750°K.

Two types of apparatus were used in these studies: (1) a longitudinal apparatus in which the sample is supported and driven on one end while it is suspended within a temperature-controlled vacuum enclosure, and (2) a flexural apparatus in which the sample is supported in a horizontal position by means of glass fibers looped over each end. In both cases, the samples are driven by a magnetostrictive transducer, but the pickup in the first case is electromagnetic while a phonograph cartridge crystal is used in the second apparatus. Sample sizes are usually about 4 to 5 inches long and 1/8 to 1/4 inch square or diameter. The same sample may be measured in both apparatus. The accuracy of the dynamic modulus and internal friction is believed to be 0.2 and 5 per cent respectively.

The internal friction of the as-deposited pyrolytic carbon and the vitreous carbon are low (less than 7×10^{-4}) and exhibit no pronounced peaks. In contrast, the graphites having crystallites which possess good three-dimensional order have a large, rather broad internal friction peak near room temperature. The height of this peak varies from 50 to 110 $\times 10^{-4}$ depending upon crystallite size and the previous thermal and mechanical history of the sample. A relaxation in the dynamic modulus is associated with this peak. The peak is destroyed by annealing above 450°K or by room temperature neutron irradiation. No evidence of the low temperature (about 50°K) peak reported by Tsuzuku[1] was found.

Some of the peaks observed in the present work are believed to be associated with the movement of basal plane dislocations. It is interesting to note that the internal friction behavior of the pitch-bonded natural graphite, commercial graphites and stress-annealed pyrolytic graphite is so similar, and that the internal friction of carbon materials which do not possess three-dimensional order is small. Observations, thus far, imply that the major contribution to the internal friction of graphites is caused by the crystallites

and that the binder is relatively unimportant over the temperature range investigated. On the other hand, the dynamic modulus is strongly influenced by both the filler and binder.

Low dose (2×10^{15} to 1×10^{17} fast neutrons/cm^2) room temperature reactor irradiation markedly affects both the dynamic modulus and the internal friction of good polycrystalline graphite or stress-annealed pyrolytic graphite. The dynamic modulus increases by 10 to 50 per cent depending upon the dose. Besides destroying the internal friction peak near room temperature, this irradiation produces two new peaks, one at about 160°K and one near 380°K. In addition, the internal friction increases markedly near 470°K and then abruptly decreases above this temperature. Concurrent with this abrupt decrease, the dynamic modulus increases sharply to a maximum at about 530°K. A further rise in temperature causes the dynamic modulus to decrease. The virgin value is obtained by 750°K. Some possible explanations for this behavior are presented.

---

(1) T. Tsuzuku and M. H. Saito, "Internal Friction Studies on Graphite" Chemistry and Physics of Carbon Volume IV, Edited by P. L. Walker, Jr., Marcel Dekker, New York (in press)

* Supported by U. S. Atomic Energy Commission on Contract No. AT(30-1)-1710.

+ North American Aviation Fellow, 1964-1967