OBSERVATIONS ON THE TEMPERATURE DEPENDENCE* OF YOUNG'S MODULUS OF GRAPHITES

by

P. E. Armstrong

Los Alamos Scientific Laboratory
The University of California
Los Alamos, New Mexico

ABSTRACT

The general characteristics of the changes in Young's modulus of polycrystalline graphite with temperature are well known; with the modulus decreasing with increasing temperature to a minimum at 300 to 400°C, and then increasing to a broad maximum in the region of 2200°C. Mason and Knibbs (1) in a recent report proposed a set of equations to describe a structural model which would produce these characteristics, and obtained experimental data on British Reactor Grade Stock. The experimental evidence seemed to support the general aspects of the theory, but produced certain conclusions that were unreasonable, such as the prediction of 50 volume per cent thermally created voids at room temperature. However, other evidence indicates that these authors made an unfortunate choice of the general form of the equation that relates an increase in void volume to a corresponding decrease in modulus. When the model is modified to more accurately account for the generally observed behavior of graphites in this respect, the predicted void fraction is much closer to the range of observed values. Mason and Knibbs experimental verification of the proposed model consisted of evaluation of the slope of the curve of the modulus versus temperature, first below room temperature, where the slope is not significantly influenced by changes in thermally created void volume caused by internal accommodation of crystallite thermal expansion, and second, at temperatures around 600°C, where the void-filling process is active. The difference in the two slopes is then a measure of the influence of the void-filling process on the modulus.

An experimental program is underway to produce values of the slopes of the curves of Young's modulus versus temperature for several commercial graphites of widely differing characteristics, which should establish the range of values that can be expected to occur, and to study in detail several systems. One such system is ZTA graphite manufactured by the National Carbon Company. Samples cut in the form of rods with the rod axis parallel to the pressing direction of this hot-worked graphite can be extended by creep at 2500°C as much as 30 per cent with very little change in lateral dimensions. The room temperature modulus of the resulting specimens initially decreases very rapidly with decreasing density but approaches a constant value with further decreases in density. An explanation for this behavior based on

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microscopic evidence may be that the initial extensions create increasing numbers of plate-like voids having a preferred orientation of the plane of the void perpendicular to the axis of extension. Further extension beyond some value like 8% tends to change the character of existing voids rather than create new voids. This change can be regarded as an increase in the dimension perpendicular to the plane of the original plate-like void, thus causing the initial essentially two-dimensional voids to increase in volume more rapidly than in area. The initially created voids would have a much greater effect in decreasing the modulus than indicated by the reduction in rod density, while the second process of increasing void volume but preserving the cross-sectional area would have a much smaller effect.

An alternate and perhaps concurrent explanation for the observed behavior could be a strengthening of the remaining graphitic structure with increasing void fraction. Comparing the slopes of the curves of modulus-versus -temperature in the regions where the void filling mechanism is believed to be operable and where it is not, should show (1) if the first explanation is correct, that the lower temperature slopes remain essentially constant and negative throughout the range of extensions, while the slopes at higher temperatures increase rapidly in the positive direction with increasing void fraction, then remain relatively constant at higher values of void fraction, or (2) a change in the value of the low temperature slopes if structural changes are taking place which tend to increase the overall stiffness of the specimens. The results of this experimental program will be presented along with a discussion of the model proposed by Mason and Knibbs as modified by the replacement of the modulus-void-fraction term.

Reference (1)
I. B. Mason and R. H, Knibbs, The Young's Modulus of Artificial Carbons and Graphites (A Discussion of Temperature Dependence) AERE-R 5140 D.P. Report 411 Atomic Energy Research Establishment, Harwell, February 1966.