THE HIGH TEMPERATURE CREEP BEHAVIOR OF A HEAVILY-ORIENTED GRAPHITE*

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ABSTRACT

The creep behavior of many different graphites has been studied at high temperatures. For one type of heavily-oriented graphite (ZTA), the creep behavior has been studied quite extensively for samples whose tensile axes were "against the grain" or parallel to the "average" "c"-axes for the piece; and for samples whose tensile axes were cut "with the grain" or perpendicular to the "average" "c"-axes of the piece. Although this ZTA graphite is more than twice as strong in one direction, little information is available on the influence of sample orientation with respect to the "average" crystal orientation of the overall piece. This investigation was conducted in an attempt to clarify the creep behavior of samples tested both in tension and compression with respect to their "average" crystallographic orientations not only at 0° and 90° to the average "c"-direction, but at a number of intermediate orientations.

Specimens for tensile creep and compressive creep were cut from a graphite billet at 0°, 8°, 20°, 30°, 45°, 60°, 70°, 82°, and 90° to the longitudinal axis of the billet ("c"-direction or "against the grain"). For each test, the sample was heated in a vacuum of about 5×10^{-5} torr to 2000°C. The furnace was then filled to a pressure of 2 psig with either helium or argon, and the sample heated to the testing temperature. Strain was measured by following the movement of fiducial markers on the sample image which was projected on a ground glass screen.

The tensile creep tests showed that the creep rate for the same test conditions was high for samples whose tensile axes were parallel to the "average" "c"-axes and very low for samples cut at right angles to this; the difference in rate being about five orders of magnitude. The creep rates for the intermediate angles were between these values with the graphic plot of creep rate versus angle being fairly well represented by a "cosine"-shaped curve. Cracks formed perpendicular to the average "c"-axes or along the basal planes, and fracture tended to follow these cracks. Activation energies were measured for a number of different orientations and an average value of 250,000 calories was obtained for all crystallographic orientations. The activation energies were determined by measuring the creep rates immediately before and immediately after a change in temperature. The stress dependence was higher than was measured for some other grades of graphite ($n = 8$), but again this dependence was not related to crystallographic orientation. The stress dependence was determined from measurements of creep rates immediately before and again immediately after changes in creep stress. Anelastic recovery on removal of the stress was also measured for one or two hours at temperature as a function of crystallographic orientation. The anelastic recovery was considerable, and appeared to be about 25% of the plastic strain. Again, the amount of recovery did not appear to bear any relationship to the orientation. The ductility, or

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strain to fracture, was low for samples whose tensile axes were nearly parallel to the "average" basal plane and high for samples oriented at right angles to this.

Similar experiments were conducted for samples loaded in compression. In compression the creep rate was highest for samples cut at 45° to the "average" "c"-axes with those oriented at 90° having the lowest creep rate. The range of creep rates, however, was less than one order of magnitude in compression, whereas, it was five orders of magnitude in tension. This difference can probably be accounted for on the basis of crack growth. Activation energies were measured and gave results similar to those in tension. The stress dependence in compression was also measured as a function of orientation angle. This dependence was the same as that for tension.

The results indicate that the creep mechanism or mechanisms are the same for samples strained in either tension or compression with one notable exception; namely, that of crack propagation and growth. Strained samples were examined by metallographic techniques to better understand the structural changes which took place.