RELATIONSHIP BETWEEN THE STRENGTH PROPERTIES OF GRAPHITE AND THE TEMPERATURE OF ITS PROCESSING


The strength characteristics constitutes some of the most important properties of any construction material, including graphite. According to some authors [1] several simple processes take place at the same time when graphite undergoes deformation.

One of the most important factors determining strength is the degree of perfection of the crystal structure of the graphite. The degree of perfection may be varied over a wide range by varying the temperature at which the semifinished material is processed — the parts under consideration being molded and heat-treated at 1300°C.

In this paper we shall consider the manner in which certain strength characteristics of carbon materials vary with the processing temperature. As subjects for study we took materials molded from petroleum coke of the KNPS type: some (GMZ) being roasted at 1300°C and others not being roasted at all (KPG); we also studied a composite of natural graphite with semicoke (ER). The first two materials had a charge composition of similar coarseness. However, the structural characteristics of the KPG materials (arising from the use of unroasted coke) imparted higher strength indices than those of the GMZ graphite.

In the ER material only the crystal structure of the semicoke altered on heat treatment; the filler (natural graphite) remained unchanged.

A number of physicomechanical characteristics were determined: the compressive strength \( \sigma_c \) (using samples 8 mm in diameter and 10 mm high) was determined in an MR-0.5 test machine to an accuracy of \( \pm 1\% \), the dynamic elastic modulus of the first kind \( E \) was derived from the frequency of the natural longitudinal vibrations in samples \( 4 \times 4 \times 40 \) mm in size, using an RIU-2 test machine with an acoustic ZG-12 generator [2] (the measuring error never exceeded 5-10\%), the hardness was measured on a TP hardness meter by the Brinell method. In conformity with All-Union State Standard 10241-40, the hardness was expressed in the form of \( H_2.5(15.6)10 \) for the test conditions chosen [3] (the 2.5 refers to the diameter of the test sphere in mm, the 15.6 to the applied load in kg/cm\(^2\), the 10 to the time under load in sec). We also determined the specific surface area of the pores, using the method of low-angle x-ray scattering [4].

At the same time we determined a number of properties enabling us to estimate the structural state of the material. The x-ray structural characteristics (lattice parameter \( C \), diameter of the coherent scattering regions \( L_q \), degree of perfection or graphitization*) were determined in a URS-50IM diffractometer with an SRS-1-0 scintillation counter and an SSS measuring and recording system. The recording were made in Cu K\(_\alpha\) radiation with powder samples, using a standard sample composed of natural graphite from the Taiginsk region (the absolute error in measuring the lattice parameters was no greater than 2-3 \( 10^{-3} \) Å).

We also measured the electrophysical characteristics closely related to the crystal-lattice ordering processes [5]: the Hall coefficient, the magnetoresistance in a transverse magnetic field of 18.5 kOe (characterizing the free electron concentration), and the electrical resistance measured with a double bridge apparatus, using samples \( 4 \times 4 \times 40 \) mm in size (the error in these measurements never exceeded 0.5 \( \Omega \cdot \text{mm}^2/\text{m} \).

*From the intensity ratio \( J_{112}/J_{110} \).

Changes taking place in the compressive strength \( \sigma_c \), the dynamic elastic modulus \( E \), and the Brinell hardness \( HB \) of semifinished GMZ (continuous lines), KPG (broken lines), and ER (dotted and dashed lines) with processing temperature.

All these properties were determined at room temperature.

Cylinders 40 mm in diameter and 45 mm long, cut from industrial billets annealed at 1300°C, were processed in laboratory furnaces at 1300-3000°C in a protective atmosphere. The structural characteristics of the resultant materials varied over a wide range. The strength characteristics varied nonmonotonically with processing temperature, a maximum appearing in the range 2100-2400°C (Fig. 1). According to S. V. Shulepov [6] the maximum was due to a certain disordering of the structure arising from the removal of foreign atoms during the graphitization. The height of the maximum is governed by the characteristics of the material: it reaches its highest value in KPG. If a large proportion of the unroasted coke is replaced by natural graphite (as in the ER material) the maximum almost vanishes.

Fig. 1. Changes taking place in the compressive strength \( \sigma_c \), the dynamic elastic modulus \( E \), and the Brinell hardness \( HB \) of semifinished GMZ (continuous lines), KPG (broken lines), and ER (dotted and dashed lines) with processing temperature.

Fig. 2. Relation between the compressive strength (allowing for porosity) and the diameter of the crystallites for samples of various semifinished materials heated-treated at 1300-3000°C.

Fig. 3. Relation between the compressive strength (allowing for porosity) and the specific surface of the pores for semifinished samples of KPG (1) and GMZ (2) based on pitch (3) and pyrolytic (4) cokes.