SUDDEN CHANGES OF VACUUM IN GRAPHITE AT A PRESSURE OF 0.5 Mbar

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A shock wave was produced in graphite by the impact of an aluminum plate scattered by the products of an explosive charge up to 5.5 km/sec. The construction of the measuring system to measure the wave velocity is shown schematically in Fig. 1a, and the arrangement used to measure the velocity of the surface is shown in Fig. 1b. The plate-striker 1 was 3.7 mm thick, the aluminum screen 2 was 2 mm thick, and the graphite specimens 3 had a diameter of 60 mm and an initial density of 2.07 ± 0.05 g/cm^3. The specimens were pressed from powdered graphite grade TKB GOST 4404-58.

When measuring the wave velocity the specimens consisted of two layers. The thickness of the first layer from the screen was varied in each experiment. The velocity was measured in the second layer, which had a constant thickness of approximately 3 mm. The electrical contact pickups 4 in this case were made of PÉV-2 wire 0.15 mm in diameter. The distance between the contacts was 8 mm. This choice eliminated the effect on the measurements of the action of the extraneous discharge from the openings for contacts of the first level.

In the experiments in Fig. 1b the specimen was a single-layer specimen. Electrical-contact pickups of PMV-0.12 wire in a copper tube of external diameter 1.6 mm were placed above its surface at distances of 0.5 mm and 5.5 mm.

The time intervals between the closing of the electrical contact probes were recorded on electric-spark equipment. The average velocity was determined from the time intervals and the known base at which the contacts were set. The results of the measurements are shown in Fig. 2 in the form of two relations W(x) and D(x), where D is the velocity of the shock wave, W is the velocity of the surface, and x is the thickness of the graphite specimen when measuring W and the distance from the screen to the middle of the measurement base when measuring D. Approximating straight lines and a curved line were drawn by the method of least squares.

In our measurements of W as a function of x the same results were obtained as in [1]; there is a break at $x_1 = 7$ mm, and an anomalous decay in the value of W is observed at the point of discontinuity. On the D–x curve at the point x_1 the value of the wave velocity remains constant. In the neighborhood of the point x_1 the value of the wave velocity falls sharply by approximately 1 km/sec. The decay of W and D for specimen thicknesses greater than x_1 is due to the action of the wave unloading, propagating from the rear side of the impacting plate.

The opinion has been expressed [1, 2] that the anomalous behavior of W(x) in the first part is due to a reduction in the pressure on the wavefront due to a phase transition (with a reduction in volume) within the compressed material, which occurs after a certain time delay (the so-called "phase unloading"). In this case there should also be a reduction in the wave velocity; i.e., there should also be a wave unloading.

Our results show that the unloading of the wave is only apparent, since the velocity of the shock-wave front in graphite in this part is constant. In our opinion the results of the measurements of W as a function of x can be interpreted in another way. We will assume that the wave in the graphite has a complex profile with an abrupt change at the front and a gradual increase in pressure (the two-wave configuration or a smooth profile

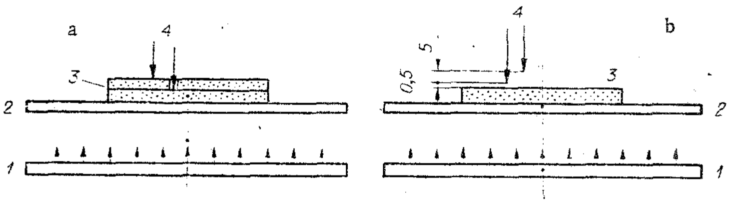

Fig. 1

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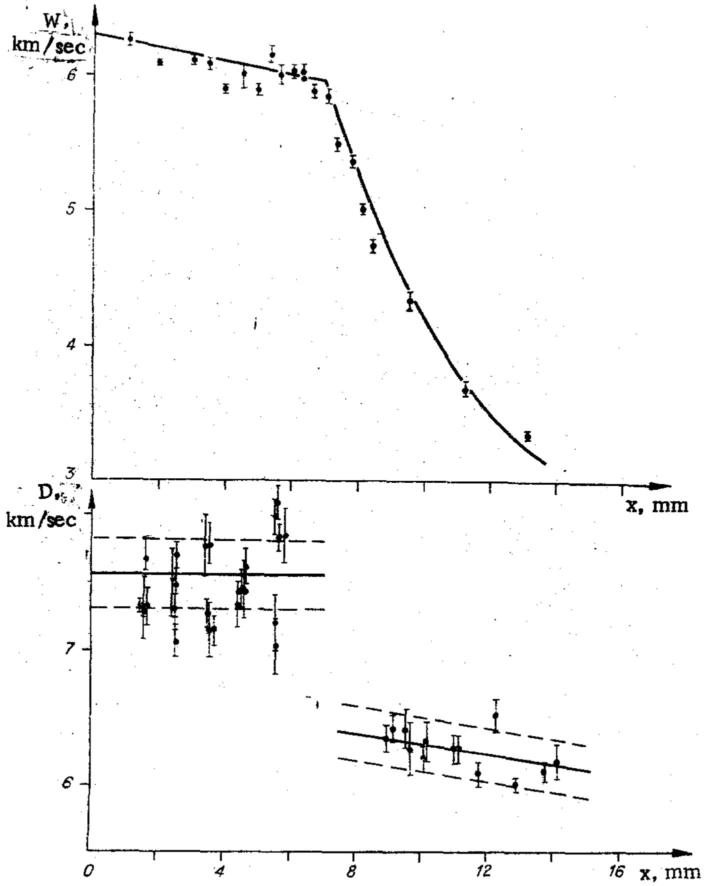

Fig. 2

[3]). Then a constant wavefront velocity will be measured with the electrical contact probes along all the paths of its motion until the unloading wave from the rear side of the striker arrives at the wavefront, as was obtained in our experiments. When this wave emerges at the free surface the latter should accelerate from a distance, since the rear parts of the wave carry a higher pressure.

The reduction in the velocity of the free surface as the thickness of the specimen increases, i.e., with the lengths of the paths traversed by the shock wave in the graphite, can be explained by stretching of the wave profile as it moves forward. So long as the wave (or the wave system) has small width, the total acceleration of the free surface from the first of its sudden changes to the maximum velocity occurs before arrival at the first contact level (in our case on a base of 0.5 mm). In this case, the W−x curve should have an initial horizontal part, small in value, but due to its smallness it is not recorded. For a large specimen thickness and, correspondingly, a more extended wave profile the accelerated surface will traverse the part of the measurement base with a velocity less than the maximum and an average velocity will be recorded in the experiment which is also less than the maximum. When the thickness of the specimen is increased further the recorded velocity W will fall monotonically, approaching a constant value determined by the mass velocity of the material behind the leading edge itself. The spreading of the profile is particularly obvious in the case of the two-wave configuration, since the rear wave lags even more behind the front wave.

Under our conditions for a finite thickness of the striker the rear unloading begins to reduce the pressure in the rear parts of the wave profile, leading to a reduction in the velocity of the free surface until the underloading reaches the leading edge of the wave itself. This actual reduction in the velocity will be superimposed on the apparent reduction, leading to a more rapid drop in W. In our experiments we were unable to determine the point where the action of the rear unloading on the rear part of the profile began.

The break in the W−x curve at $x = x_1$ is, in our opinion, the result of the arrival of the sudden change in unloading at the leading edge. This sudden change also causes a corresponding jump in W(x), but it is recorded as a break due to the finite measurement base. The sudden change in the unloading in this case is confirmed by our measurements of D as a function of x.

The appearance of a jump (a shock wave) in the vacuum is characteristic for loading processes in materials undergoing phase transitions [3]. In the case of graphite this sudden change indicates simultaneous graphitization of diamond into which the graphite is converted during the loading process.

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STABILITY OF A THIN ELECTRIC ARC

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1. Introduction. Assuming a thermal plasma and neglecting the emission and density variation due to electromagnetic forces, we write the dimensionless equations for a steady electric arc burning in a cylindrical channel as follows [1]:

$$\begin{gathered} r^{-1}[r\lambda(T)T']' + E^2\sigma(T) = 0, \\ r^{-1}(rH)' = \sigma(T),\ \rho T = 1,\ c_p = c_p(T),\ \mu = \mu(T), \\ E = \text{const},\ H_\varphi = EH. \end{gathered} \tag{1.1}$$

One can select

$$T|_{r=0} = 1,\ T'|_{r=0} = H|_{r=0} = 0,\ T|_{r=1} = T_R \tag{1.2}$$

as the boundary conditions. The constant E is determined from the three boundary conditions for the first equation of the system (1.1). Here T, ρ, σ, E, H_φ, λ, c_p, and μ are the dimensionless temperature, density, electrical conductivity, electric field intensity applied along the z axis, φ-th component of the intrinsic magnetic field intensity, thermal conductivity coefficient, specific heat at constant pressure, and the dynamic viscosity coefficient; T_R is the dimensionless temperature on the channel wall; and r, φ, z are cylindrical coordinates; here and below a prime denotes a derivative with respect to r.

The values of the corresponding parameters on the channel axis (with subscript m) are the scale factors of T, ρ, σ, λ, c_p, and μ. The scale factors of the electric field intensity and the magnetic field intensity are

$$E_m = \sqrt{\lambda_m T_m/\sigma_m}/R_m,\ H_{\varphi m} = E_m\sigma_m R_m.$$

The stability of an electric arc has been investigated in [1] with respect to symmetrical perturbations with viscosity taken into account. It turned out that for the critical curves (we will mark the critical parameters below with a subscript c) which separate the stable regions from the unstable ones the phase velocity of the perturbations is equal to zero, and the stability boundary is determined by the value of the product of the Stewart number by the viscosity parameter. The equations along with the boundary conditions are of the form

$$\begin{gathered} p' = -E^2Q[H(\sigma e + (d\sigma/dT)\theta/\lambda) + \sigma h] + 2r^{-1}(r\mu v')' - \\ -\mu(2/r^2 + k^2)v + \mu w' - (2/3)\{\mu[r^{-1}(rv)' + w]'\}', \\ r^{-1}(r\mu w')' = -k^2p - E^2k^2QHh + k^2r^{-1}(r\mu v)' + \\ + (4/3)k^2\mu w - (2/3)k^2\mu r^{-1}(rv)', \\ r^{-1}(r\rho v)' = -\rho w, \\ r^{-1}(r\theta')' = c_pT'\rho v + k^2\theta - E^2(2\sigma e + (d\sigma/dT)\theta/\lambda), \\ r^{-1}(rh)' = \sigma e + (d\sigma/dT)\theta/\lambda,\ e' = k^2h/\sigma; \end{gathered} \tag{1.3}$$

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