OBTAINING THE LOAD-EXTENSION CURVES OF SAMPLES SUBJECTED TO AN EXPLOSION LOAD

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The energy of explosives has been increasingly used in recent times for the mechanical testing of construction materials subjected to high rates of deformation [1-8]. We describe in the present paper a small apparatus for the uniaxial expansion testing of samples with the aid of explosives at deformation rates of about 10^3 sec^{-1}; we report on some results of testing steel and aluminum alloy samples.

The apparatus for load application by explosion (Fig. 1a) consists of a layer of an explosive 10, an impact-transferring member 9, a damper 8, a receiver cap 7, and a cylindrical waveguide 4 through which an expanding force is transmitted to the sample. Reliable contact of the lower face of the waveguide with the shoulders of the sample was obtained with the aid of a threaded junction. The sample and waveguide were centered by means of a polyethylene washer 3. Since the deformations are measured only in a passing expansion wave, the sample end opposite to the end to which the load was applied was not firmly fixed. A bolt 5 was used in the experiments to suspend the testing apparatus from frame 11 behind the free end of the sample.

Figure 1 b shows both the form and the dimensions of steel and AMG-6 alloy samples. The transverse dimensions of samples made of the AD-1 and D-16 aluminum alloys were increased (see Table 1). In the tests the sample portion 1 experienced an elastoplastic deformation, whereas sample portion 6, which acted as a dynamometer, underwent only an elastic deformation. The length of the dynamic sample section was chosen so that a recording of the deformation was obtained before the elastic deformation wave reflected from the free end of the dynamometer arrived. Pairs of strain gauges were glued to diametrically opposite sides of the sample and connected in series lest a possible asymmetry of the sample deformation have any influence.

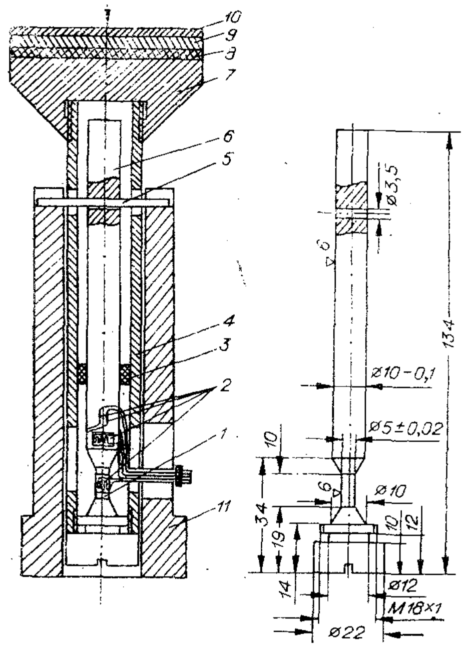

Fig. 1

A potentiometric circuit with a dc source was used for the transducers in the experiments. A double-beam S1-18 oscillograph with a transmission band ranging from 0.1 MHz to 1 MHz was used as the recorder. The measuring circuit was calibrated in tests by shunting the transducers with a calibrated inductionless resistor. The dependence (measured with the dynamometer) of the deformation upon the time, $\mathcal{E}_q(t)$, was used to derive with a simple conversion the time dependence of the stress in the affected sample section (because the modulus of elasticity E of the majority of metals is practically independent of the deformation rate):

$$\sigma(t)=\mathcal{E}_q(t)E\cdot\varkappa$$

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TABLE 1

Material	$\dot{\mathscr{E}}_u$, sec^{-1}	$\dot{\mathscr{E}}_p$, sec^{-1}	$\sigma_{s_{0,2}}$, kg/mm^2	$\sigma_{s_{0,2}}$, kg/mm^2	d_1, mm	d_2, mm
AD-1	225	700	13	24	10	24,5
D-16	200	600	14	25	10	24,5
AMG-6	300	1700	15	16	5	10
Kh18N10T	400	1400	25	38	5	10
36KhTYu	560	2000	79	84	5	10
Steel 40Kh	400	2000	42	78	5	10

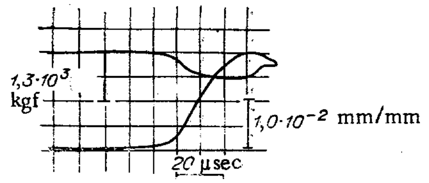

Fig. 2

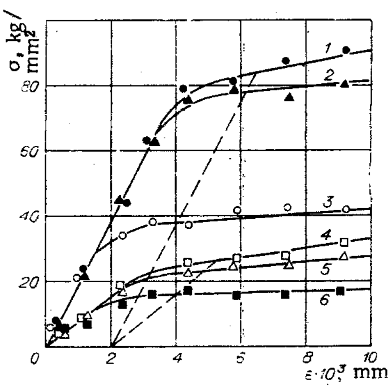

Fig. 3

($\varkappa$ – o denotes the ratio of the cross sections of the dynamometric sample portion to the affected sample portion).

The dependence of the deformation of the sample upon $\mathscr{E}(t)$ was directly determined from stress-strain diagrams (Fig. 2). The dynamic stress curve, i.e., the deformation $\sigma = f(\mathscr{E})$, was derived from the experimental dependences of the stress upon $\sigma(t)$ and of the deformation upon $\mathscr{E}(t)$ by eliminating the time as a parameter.

When the stress–deformation diagrams were derived, it was assumed that the force acting in various cross sections of the sample is constant while the wave propagates through the sample. This condition was never rigorously fulfilled, because when the wave runs through the sample, the sample is transformed (expanded) particularly strongly in the range of elastoplastic deformations. Therefore, in order to reduce force incongruities, the affected sample section must be shortened [9, 10]. But this sample section must still suffice for measuring the deformations with strain gauges at a 5-mm base and in a zone free of boundary effects.

The greatest total error of the stress and deformation measurements consists of the error made in the oscillograph measurements (less than ±10%), the error of the oscillograph readings (less than ± 5%), and the error resulting from the finite length of the transducers owing to the wave-like effect under consideration and to the dependence upon the deformation rate (this error was less than ±5% at a base length l = 5 mm of the transducer at deformation rates of up to 10^3 sec^{-1} [11]) and amounts to less than ±20%.

Figure 3 shows stress–deformation diagrams constructed from the results of the dynamic sample testing. The diagrams were obtained for each material by testing at least three samples. We used in our experiments samples of 40Kh steel (curve 2), Kh18N10T steel (curve 3), the 36NKhTYu alloy (curve 1), and the AD-1 (curve 5), AMG-6 (curve 6), and D-16 (curve 4) aluminum alloys. Some results of the tests are listed in Table 1.

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