INVESTIGATION OF THE CLEAVAGE FRACTURE OF CONDENSED SOLIDS

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Fracture of a specific kind occupies a special place in the mechanics of deformable media. Cleavage occurs because of the wave flow being realized in a specimen of finite dimensions under high-velocity impact, or a contact explosion, and is in a separate part of the specimen, near the free surface, from the main mass of the specimen. It can be said that cleavage – dynamic fracture – is universal in nature. It is observed for different solids, metals, multilayer composites, hard rocks, polymers. The formation of cleavage has also been determined experimentally even for fluids. Fluids under intensive dynamical loading are similar to solids, and undergo cleavage fracture. In particular, the formation of cleavage was noted in water, glycerine, and oil in [1]. Papers are devoted to investigations of methods of determining and obtaining the most quantitative characteristics of cleavage fracture, namely: [2] for water and ethyl alcohol; [3] for glycerine; [4, 5] for glycerine and mercury; and [6] for water, ethyl alcohol, glycerine, and acetone. Moreover, cleavage fracture in easily melted metals, which remain in the liquid state after shock loading and subsequent unloading, is investigated in [7].

Data for the greatest possible number of groups of condensed bodies, including liquids, are necessary for the construction of dynamical fracture models under cleavage in condensed bodies.

Metals and alloys (magnesium, steel St. 3, the aluminum alloy D16, lead), liquids (water, ethyl alcohol, glycerine, acetone), and plastics (Plexiglas, caprolon, polystyrene, paraffin) are investigated in this paper. The experimental technique and method of processing the results used here are similar to those used in [6].

The experimental results obtained are displayed in Figs. 1-3. The results for lead in Fig. 1 are: 1) the data from this research; 2) [8]; 3) [9]. The results in Fig. 2 are for glycerine I, water II, ethyl alcohol III: 1) data from this research; 2) [2]; 3) static rupture strength [10, 11]. The results in Fig. 3 are for Plexiglas I, polystyrene II, paraffin III, caprolon IV: 1) data from this research; 2) [2]; 3) static rupture strength [12].

The procedure for reducing the data of other researchers to the variables rupturing stress p_* and strain rate $\dot{\varepsilon}$ is described in [13]. The results for steel St. 3 and the aluminum alloy D16 are presented in [13].

The materials investigated were separated into two groups: with a linear dependence of the rupturing stress on the strain rate

$$p_* = a_0 + a_1\dot{\varepsilon} \quad (1)$$

and with a power-law dependence

$$p_* = b_0(\dot{\varepsilon})^{b_1}.$$

Materials with the linear dependence (1) have considerably less viscosity in the initial state. For such materials the change in p_* with $\dot{\varepsilon}$ can be related qualitatively to the viscosity η: $p_* \sim \eta\dot{\varepsilon}$. In particular, this result follows from the data for the viscous cleavage considered in [14], for instance. Moreover, we can arrive at this dependence by selecting the viscosity by means of [15] under the assumption that the rupture pulse duration is greater than the relaxation time and that the strain rate is inversely proportional to the pulse duration.

Let us examine the property noted for the different kinds of bodies. The change in rupture strength in a broad range of strain rate variation is shown qualitatively in Fig. 4. The continuous section corresponds to static tests, the dash–dot to quasistatic, and the dashes to dynamic loading by an explosive method. Starting with the strain rate $\dot{\varepsilon} \simeq 10^3$ sec^{-1}, the dynamic effect appears. Such a general nature of the change in strength with the strain rate was noted in [16] for minerals (dolomite, limestone, granite, basalt), in [17] for certain metals, and in [13] for the metals copper, aluminum, and steel.

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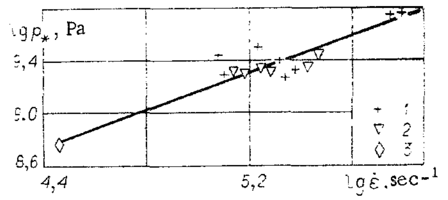

Fig. 1

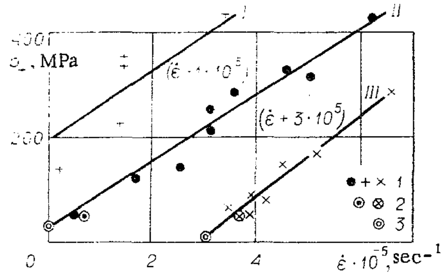

Fig. 2

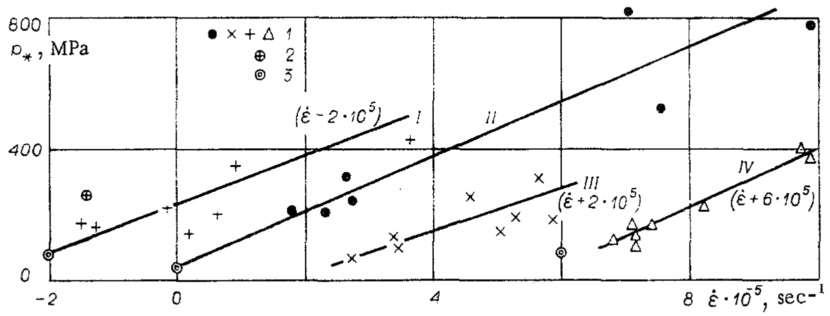

Fig. 3

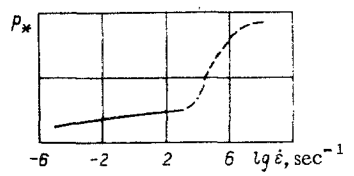

Fig. 4

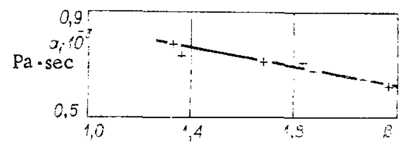

Fig. 5

Analysis of the results permits tracing the correlation between the coefficients a_0 and a_1 in (1) and the mechanical and gasdynamic characteristics of the materials studied. The values of the coefficients a_0 are similar to the static rupture strength values. Values of the coefficient a_1 correlate with the magnitude of the coefficient β in the linear relationship $D = c_0 + \beta u$ between the wave D and mass u velocities for a shock. Values of the coefficient a_1 are compared in Fig. 5 with the corresponding values of the coefficients β. The experimental points are described by a linear dependence $a_1 = 1 - 0.17\beta$ displayed in Fig. 5 by the continuous line.

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THE VELOCITY PATTERN IN INDENTATION BY A STAMPING TOOL

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The planar deformation is considered when a hard smooth stamping tool enters an elastoplastic medium bounded by a plane. In the limiting state, the tool with a flat base moves downwards with a speed v_0.

1. Continuous Solution for Velocities. Figure 1 shows the network of slip lines corresponding to Prager's solution [3], which is a combination of the solutions due to Prandtl [1] and Hill [2].

In what follows we use not only a Cartesian coordinate system (x, y) but also a curvilinear system (ρ, θ), where

$$x = 1 + \rho \sin \theta, \; y = -\rho \cos \theta.$$

The width of the tool is taken as 2.

The length of the segment A_1B_1 is 2λ. Parameter λ can take any value in the range $0 \le \lambda \le 1$ and defines the dimensions of triangle A_1B_1C.

The following is the velocity pattern for the network of Prager slip lines (Fig. 1):

$u = 0,$	$v = -v_0$	in triangle $A_1B_1C,$
$u = v_0,$	$v = -v_0$	in triangle $B_1T_1B,$
$u = v_0/2,$	$v = -v_0/2$	in rectangle $CB_1T_1T,$
$u = \sqrt{2}v_0 \cos \theta,$	$v = \sqrt{2}v_0 \sin \theta$	in segment $T_1B_1D,$
$u = (v_0/\sqrt{2}) \cos \theta,$	$v = (v_0/\sqrt{2}) \sin \theta$	in region $TT_1D_1D,$
$u = v_0,$	$v = v_0$	in triangle $BD_1E_1,$
$u = v_0/2,$	$v = v_0/2$	in region $D_1E_1ED,$

where u and v are the components of the velocity vector along the x and y axes, respectively. The tangential velocity component is discontinuous along the lines CB_1, CTDE, $B_1T_1D_1E_1$. In the limiting cases of $\lambda = 1$ and 0 we obtain the Prandtl and Hill solutions. Other possible velocity solutions have been considered in [4].

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