wave produces electric polarization along the wave normal. This effect may account for the appearance of quasi-static electric fields in the near (nonwave) zone.

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CAVITATION DYNAMICS IN REFLECTION OF A COMPRESSION PULSE FROM THE INTERFACE OF TWO MEDIA

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This paper is concerned with the reflection of a flat compression pulse, propagating in a condensed medium, from the surface of separation with a barrier, whose dynamic rigidity is low. This situation occurs in experiments on recording separation in low-strength substances – glycerol [1] or rubber [2]. In this case, as a result of interference of the incident and reflected rarefaction waves negative pressures are generated at some distance from the interface in the medium under study; these pressure gives rise to the appearance and growth of cavities – cavitation. The processes illustrated in Figs. 1 and 2, which show diagrams of the time t versus Langrangian coordinate h and the pressure p versus the mass velocity u of the material. The aim of this work is to determine the motion of the boundaries of the cavitation zone and the manifestation of this motion on the profile of the velocity of the contact boundary.

We study, in the acoustic approximation, cavitation in a medium whose tensile strength is equal to zero. We denote by $i_1 = \rho_{01}c_1$ and $i_2 = \rho_{02}c_2$ the dynamic rigidities of the material of interest and the barrier, respectively (ρ and c are the density and velocity of sound in the material). The incident compression pulse propagates along C_+ characteristics. After the shock wave emerges on the contact surface the reflected rarefaction wave, moving along C_- characteristics, appears. The state of the particles of the material must satisfy conditions on both C_+ and C_- characteristics.

Let the distribution of the velocity in the incident compression pulse have the form

$$u = u_0 - k(c_1t - h + H),\ u = 0 \text{ for } h - c_1t \leqslant H - u_0/k.$$

Here u_0 is the maximum value of the mass velocity and the coefficient k = const. Cavitation starts at $t = \tau$ in the section h = 0 (Fig. 1), where as a result of the interaction of the rarefaction waves the pressure first drops to zero. The left-hand boundary of the cavitation region is transported by the C_- characteristic passing through this point (the line AB). After the reflected rarefaction wave encounters the end of the compression pulse at the point $t = u_0/2kc_1$, $h = H - u_0/2k$ the propagation of the cavitation zone to the left stops. From the conditions of compatibility of the states on the C_+ and C_- characteristics (Fig. 2) it follows that the pressure p = 0 is reached at the time $\tau = H/c_1 = (u_0/kc_1)/((i_2)/(i_1 + i_2))$.

The change in the velocity and pressure on the contact boundary before information about the start of cavitation reaches it is described by the equations

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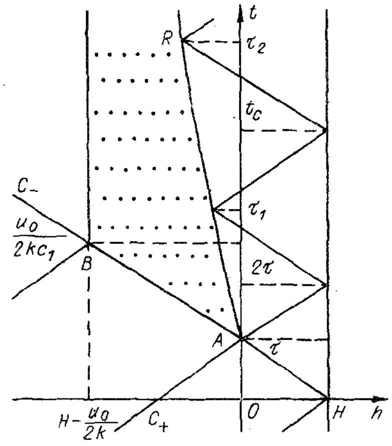

Fig. 1

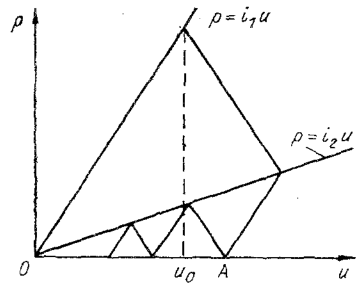

Fig. 2

$$\bar{u}(t) = \frac{2i_2}{i_1 + i_2}(u_0 - kc_1t), \quad \bar{p}(t) = i_2\bar{u}(t), \quad t \leqslant 2\tau. \tag{1}$$

As a result of the counterpressure exerted by the barrier the right-hand boundary of the cavitation region AR (Fig. 1) is displaced to the left. We shall find the law governing its motion.

From the condition that the boundary of the cavitation region is equal to zero and the requirement that the changes in p and u match along C_- characteristics with the parameters $\bar{p}$ and $\bar{u}$ on the contact boundary, we obtain the velocity along the trajectory AR:

$$u^+(t) = \frac{i_1 - i_2}{i_1}\bar{u}\left(t - \frac{H - h_R}{c_1}\right) = \frac{2(i_1 - i_2)}{i_1 + i_2}[u_0 - k(c_1t + h_R - H)], \tag{2}$$
$$\tau \leqslant t \leqslant \tau_1.$$

In Eq. (2) h_R designates the Lagrangian coordinate of the right-hand boundary of the cavitation region, and τ_1 is determined in terms of h_R and will be found below.

The average velocity of the particles of the material after cavities start to form remains constant and equal to

$$u^-(t) = 2[u_0 - 2k(H - h)], \quad t \geqslant \tau - h/c_1. \tag{3}$$

The change in the specific volume in the cavitation zone in this case is found from the equation

$$\partial v/\partial t = v_0 \partial u/\partial h = 4kv_0. \tag{4}$$

The law of motion of the boundary AR is determined as follows. On this boundary the cavities collapse under the action of the counterpressure. The mass velocity and the specific volume of the medium jump from u^- and v^- to the left of the boundary to u^+ and $v^+ = v_0$ to the right of the boundary. Therefore, for the right-hand boundary of the cavitation region we can write the equation of conservation of mass analogous to the condition on a shock: $(D - u^-)/v^- = (D - u^+)/v^+$ (D is the velocity of the boundary in the laboratory coordinate system). Taking into account the fact that behind the shock the specific volume of the material is equal to v_0, we obtain a differential equation for the trajectory of the right-hand boundary of the cavitation zone in Lagrangian coordinates:

$$\frac{dh_R}{dt} = D - u^+ = \frac{v^+}{v^- - v^+}(u^+ - u^-). \tag{5}$$

The specific volume v^- is found by integrating Eq. (4) using the initial condition $v^- = v_0$ at $t = \tau - h/c_1$:

$$v^- = v_0\left[1 + \frac{4k}{c_1}(c_1t + h - H)\right]. \tag{6}$$

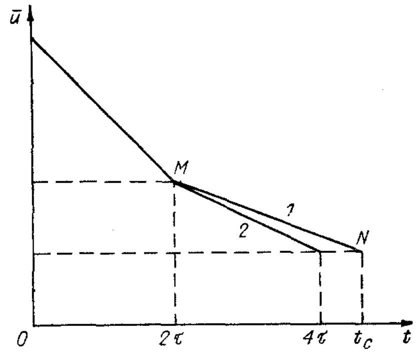

Fig. 3

After substituting into Eq. (5) the values of u^+, u^-, and v^- from Eqs.(2), (3), and (6) we obtain

$$\frac{dh_R}{dt} = -\frac{c_1}{2}\frac{(2+\delta)h_R + \delta c_1(t-\tau)}{h_R + c_1(t-\tau)}, \tag{7}$$
$$h_R = 0 \text{ at } t = \tau,\ \delta = (i_1 - i_2)/(i_1 + i_2).$$

The initial conditions are given at the singular point of Eq. (7), since at this point the numerator and denominator both vanish simultaneously. This singular point is a saddle point [3]. Two intersecting straight lines pass through it. One of these lines does not satisfy the physical formulation of the problem, while the second line gives the equation sought for the trajectory of the right-hand boundary of the cavitation zone:

$$h_R = Ac_1(t-\tau),\ \tau \leqslant t \leqslant \tau_1,\ A = -1 - \delta/4 + \sqrt{1+\delta^2/16}. \tag{8}$$

The time τ_1, up to which Eq. (8) is valid, is found from the condition $\tau_1 = 3\tau - h_R(\tau_1)/c_1$ and has the form $\tau_1 = \tau(3 + A)/(1 + A)$. Thus, the right-hand boundary of the cavitation region moves with constant velocity Ac_1, which does not depend on the slope of the incident compression pulse.

After information about the start of cavitation ($t = 2\tau$) arrives at the contact boundary the law of decrease of the velocity of this boundary changes. For $t \leq 2\tau$ the profile of the velocity is described by the expression (1), and then it is determined by the wave reflected from the boundary of the cavitation region:

$$\bar{u}(t) = \frac{i_1}{i_1+i_2}u^+\left(t - \frac{H-h_R}{c_1}\right) = \frac{2i_1(i_1-i_2)}{(i_1+i_2)^2}\left[u_0 - \frac{1+A}{1-A}kc_1(t-2\tau)\right], \tag{9}$$
$$2\tau \leqslant t \leqslant t_c = 4\tau/(1+A).$$

It can be shown analogously that for $\tau_1 \leq t \leq \tau_2$ (see Fig. 1) the line AR is described by the equation

$$(X - A_1T)^{\gamma_1}(X - A_2T)^{\gamma_2} = \text{const},$$
$$X = h_R + (\delta - \Delta)H,\ T = c_1(t-\tau) - (\delta - \Delta)H,\ A_{1,2} = -1 - \Delta/4 \pm \tag{10}$$
$$\pm\sqrt{1+\Delta^2/16},\ \Delta = \delta^2(1+A)/(1-A),\ \gamma_{1,2} = \pm(1+A_{1,2})/$$
$$/(A_1 - A_2).$$

The constant is found from the condition that AR is continuous at the time τ_1.

As analysis of Eq. (10) shows, the velocity of the right-hand boundary of the cavitation region is continuous at $t = \tau_1$. It decreases in absolute magnitude monotonically with time and lies in the range $-A_1c_1 < |dh_R/dt| \leq -Ac_1$.

Figure 3 shows profiles of the velocity of the contact surface of the specimen, having zero strength, under conditions of unloading into a medium where rigidity is lower. The curve 1 corresponds to the calculation using Eq. (9), and curve 2 was constructed neglecting the motion of the boundary AR: $h_R = 0$. For $\delta = 0.5$ ($i_1/i_2 = 3$) taking into account the motion of the right-hand boundary of the cavitation region gives a correction of greater than 26% in the slope of the profile $\bar{u}(t)$ on the section MN.

Thus, the results of our analysis show that the dynamics of the cavitation zone must be taken into account when interpreting experimental profiles obtained for the velocity of contact surfaces in the study of separation phenomena in low-strength media. The influence of the cavitation zone on the dynamics of a free surface was first observed in [4].

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DIFFUSION KINETICS WITH CRYSTAL GROWTH FROM THE GAS PHASE

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A series of relations describing the flow of matter to the surface of a crystal, growing in a sealed cylindrical ampul from a gas—vapor medium, was derived in [1-3]. It was assumed that the growth process is governed by the diffusion kinetics, but the question of when this is valid was not studied. At the same time it is necessary to assess the conditions under which the transport of matter is the limiting stage. It is known that crystals which grow in the diffusion region are distinguished by the fact that they exhibit the highest perfection. In addition, the rate of growth and the character of the impurity distribution in the case of the diffusion kinetics depend directly on technological parameters, such as the temperature gradients, the dimensions of the system, the orientation of the system, the pressure, etc.; this enables efficient control of the growth process.

Diffusion kinetics is realized in cases when the characteristic transport time τ_v is much longer than the characteristic time of the phase or chemical transformation itself. In the case of growth with the help of gas-transport reactions the chemical transformations can be schematically represented in terms of stages: adsorption of gaseous reagents on the surface of the growing crystal, chemical reaction between adsorbed molecules, and desorption of the reaction products. We denote the duration of each stage by τ_a, τ_r, and τ_d, respectively. We shall assume that a reaction of the type

$$\nu_1 A_1(g) \rightleftarrows \nu_2 A_2(g) + \nu_3 A_3(s)$$

occurs on the solid surface. Here A_i designate the chemical elements; ν_i are the stoichiometric coefficients; g and s are gaseous and solid products.

According to [4, 5], the characteristic times of the adsorption stage τ_a and desorption stage τ_d are

$$\tau_{(i)} = \delta_{(i)} \sqrt{\frac{2\pi m_{(i)}}{kT}} \exp\left(\frac{U_{(i)}}{kT}\right) \quad (i = a,\ d), \tag{1}$$

where $m_{(i)}$ is the mass of the adsorbed molecule m_a or the desorbed molecule m_d; $U_{(i)}$ is the activation energy of the corresponding process; k is Boltzmann's constant; T is the tempera-

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