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ENHANCEMENT OF A MAGNETIC FIELD IN A PERFECTLY CONDUCTING MEDIUM ON PENETRATION OF A HIGH-VELOCITY JET INTO IT

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We consider the possibility of enhancement of a magnetic field created in a conducting medium on penetration into it of a high-velocity striker moving across the magnetic-induction lines. For the case of a perfectly conducting target, an estimate is obtained for the rate of increase of the field intensity in the region of contact with the head part of the striker. A dimensionless parameter is introduced that characterizes the relationship between the rates of generation and diffusion of the field on penetration into a material of finite conductivity. Based on a model that takes into account the force action of a compressed field, the special features of the flow that arises on penetration of a high-velocity cumulative jet into a perfectly conducting target with a transverse magnetic field are analyzed.

The motion of a conducting medium with a magnetic field created in it in advance can be accompanied, under certain conditions, by considerable enhancement of it. Here, manifestation of high-power mechanical, thermal, and electromagnetic effects can occur that, in turn, are capable of influencing substantially the character of the medium motion. Some results of a computational-theoretical investigation of this effect are presented below.

The possibility of enhancement (generation) of a magnetic field in a moving deformable conducting medium follows from the equation that describes the magnetic-field evolution [1]:

$$\frac{d}{dt}\left(\frac{\mathbf{B}}{\rho}\right)=\left(\frac{\mathbf{B}}{\rho}\nabla\right)\mathbf{v}+\frac{\eta}{\mu_0\rho}\Delta\mathbf{B}\,,\quad \mu_0=4\pi\cdot 10^{-7}\ \ \text{H/m}\,. \tag{1}$$

The first term on the right-hand side of Eq. (1) controls the effect of the "freezing-in" of the magnetic field in the substance [1], while the second controls the effect of field diffusion. The first of these effects manifests itself most vividly in a perfectly conducting medium ($\eta = 0$) and lies in the fact that the magnetic-flux lines (magnetic-induction lines) are seemingly "frozen-in" in the medium, that is, they move and deform together with it, and the magnitude of the quantity $\mathbf{B}/\rho$ changes proportionally to the change in the length of the deformed magnetic lines. For an incompressible medium (ρ = const) this leads to a linear interrelationship between the elongation of the material fibers that are oriented along the lines of magnetic induction at the start of the motion and the change in the induction of the magnetic field B itself in the substance. The effect of the "freezing-in" of the magnetic field will also manifest itself in a medium that has a finite conductivity: the magnetic field created before the start of the motion must be enhanced if the motion of the medium is accompanied by tensile deformations of its material fibers initially oriented along the magnetic-induction lines. However, in media with a finite conductivity, enhancement of the magnetic field is hindered by a diffusional effect that leads to weakening of the field generation due to smoothing of its inhomogeneities when they appear. The

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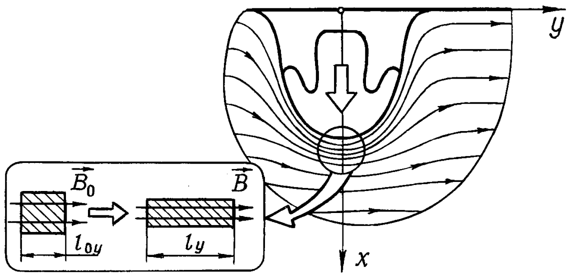

Fig. 1. Schematic diagram of magnetic-field compression in a conducting target in high-velocity penetration.

more rapidly the deformation of the medium occurs, the larger the enhancement of the field that can be attained, due to a decrease in the role of the factor of its diffusion. The influence of diffusion processes also decreases with decrease in the electrical resistance of the medium η due to a slowing down of the diffusion process.

Generation of a Magnetic Field in a Conducting Target in High-Velocity Penetration. Deformation conditions that allow one to expect intense magnetic-field generation appear on penetration of a high-velocity striker into a conducting target in which a transverse (with respect to the direction of motion of the striker) initial field is created in advance [2] (Fig. 1). Large deformations of the particles of the target [3] in the region of contact with the head part of the striker, as a result of which they are stretched transversely (along the lines of induction of the magnetic field created) and are compressed in the direction of penetration, must lead to compression of the "frozen-in" magnetic field with a sharp increase in its intensity.

Let us evaluate the rate of "pumping" of a magnetic field in the absence of its diffusion on penetration of a striker into a perfectly conducting incompressible material. We will assume that in the perfectly conducting target a homogeneous magnetic field with induction B_0 that is oriented parallel to the free surface of the medium is produced. We restrict ourselves to consideration of a plane scheme of interaction with the motion of the striker along the normal to the target and we follow the evolution of the magnetic induction in the particles of the target that are located in the plane of symmetry of the flow at the boundary of contact with the striker. The material fibers of the target that are oriented transversely and that are located in the plane of symmetry only elongate in the process of penetration without changing their orientation (Fig. 1). In conformity with the "freezing-in" principle, the magnetic field in the plane of symmetry is characterized by a single transverse component whose increase must occur in direct proportion to the transverse elongation of the particles.

Deformation of target particles that are in direct contact with the head part of the striker begins immediately after the appearance of the interaction and persists during the entire process of penetration. In evaluating the change in the transverse elongation of these particles with time, we assume that the penetration occurs with a constant velocity u_p and that the thickness of the target-material layer involved in the motion in front of the striker is equal to a value d_0 that has the order of magnitude of the transverse dimensions of the striker. Within the limits of the given layer, the velocity of the target particles located in the plane of symmetry has only a longitudinal component that changes from the value u_p at the boundary of contact with the striker to zero at the opposite boundary. In this case the characteristic rate of longitudinal deformation of the target particles in penetration is determined as $\dot{\varepsilon}_x = -u_p/d_0$. From the condition of incompressibility of the material of the target it follows that the rate of transverse deformation of its particles in the region of deformation in front of the striker is represented by the equality $\dot{\varepsilon}_y = -\dot{\varepsilon}_x$. Using this to determine the law of time variation of the length l_y of transversely oriented material fibers at the boundary of contact with the striker (Fig. 1), with account for the kinematic relation $\dot{\varepsilon}_y = (dl_y/dt)/l_y$ we arrive at the differential equation

$$\frac{1}{l_y}\frac{dl_y}{dt} = \frac{u_{\tilde{n}}}{d_0}\,.$$

Its solution with the initial condition $t = 0$, $l_y = l_{0y}$, where l_{0y} is the initial length of the fibers transverse to the direction of penetration, makes it possible to establish an exponential character of the growth of the transverse elongation of the particles l_y/l_{0y} with time; consequently, in the case of perfect conductivity of the material and a magnetic-field induction in the region of the target in front of the striker we obtain

$$B = B_0 \frac{l_y}{l_{0y}} = B_0 \exp\left(\frac{u_p}{d_0} t\right). \tag{2}$$

Thus, on penetration into a perfectly conducting medium the magnetic-field intensity at the boundary with the striker must increase e times in the time $\tau_g = d_0/u_p$.

The degree of influence of diffusion processes in a target of finite conductivity on the generation of a magnetic field can be evaluated by comparing the rates of generation and diffusion. Since the generation of the field in the medium during penetration occurs in front of the striker in a region of localization of deformations that has the longitudinal dimension d_0, as the time scale of occurrence of diffusion processes we take the characteristic time of diffusion for a layer of the conducting material of the same thickness $\tau_d = \mu_0 d_0^2/\eta$ [1]. The ratio of the characteristic times of generation and diffusion makes it possible to introduce into consideration the dimensionless parameter

$$\kappa = \frac{\tau_g}{\tau_d} = \frac{\eta}{\mu_0 d_0 u_p}, \tag{3}$$

from the value of which we can judge the importance of diffusional losses in the process of field generation. The dimension d_0 of the region of field generation in the target entering into (3) is associated with the transverse dimensions of the striker. Taking this into account, it is possible to obtain an estimate of the parameter κ for specific conditions of penetration. Thus, for high-velocity strikers that have a transverse dimension of the order of 1 mm and penetrate with a velocity of several kilometers per second into a target with a high electrical conductivity (copper, aluminum), the value of κ is equal to about 0.01. This is indicative of a substantially higher rate of "pumping" of the magnetic field under the given conditions as compared with the rate of its diffusional "dissipation."

Thus, diffusion processes should not play a determining role in high-velocity penetration that excludes the possibility of considerable enhancement of a magnetic field created in the target in advance. Under real conditions, the limits of this enhancement can be associated with thermal and mechanical effects whose manifestation is possible in strong magnetic fields [4].

Relation (2) that describes the dynamics of field generation in a perfectly conducting medium can be represented in the form

$$B = B_0 \exp\left(\frac{L}{d_0}\right), \quad L = u_p t .$$

From this it is seen that for strikers whose penetration depth substantially exceeds their transverse dimension the degree of enhancement of the magnetic field in the target can be very high. Among high-velocity strikers that offer the highest piercing power there are cumulative jets formed on explosion of an explosive charge that has a recess lined with a thin metal shell [5]. The velocity of the head part of the cumulative jet can attain 10 km/sec, and the depth of penetration into a metal target exceeds the jet diameter by two orders of magnitude. When such a jet penetrates into a conducting material with a magnetic field, conditions develop for "pumping" the field to a level at which its force action becomes comparable to the shock-loading pressure.

Model of Penetration of a Cumulative Jet into a Target with a Magnetic Field. To elucidate the specific features of magnetic-field generation in a target on penetration of a cumulative jet into it with allowance for the force action of the field, we consider a model of this process assuming perfect conductivity and incompressibility of the materials of the target and the jet. In view of the high-velocity character of the interaction, we neglect the strength properties of the materials. Remaining as before within the framework of a plane scheme of the interaction, with the jet moving normal to the free surface of the target, we use as a basis the hydrodynamic theory of penetration [5].

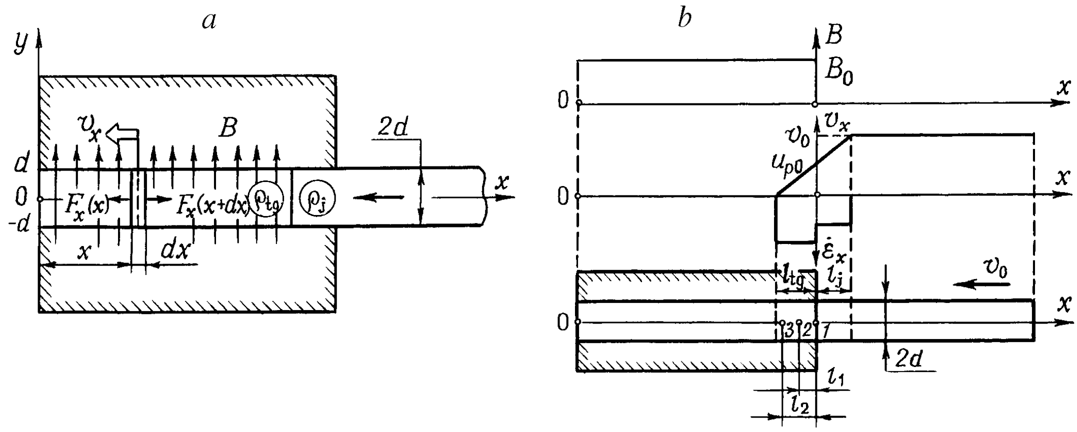

Fig. 2. Toward formulation of the problem of penetration of a cumulative jet into a conducting target with a transverse magnetic field: a) computational scheme; b) assignment of initial conditions of interaction.

Treating the process of penetration as a collision of two jets of incompressible liquids (Fig. 2a) with densities ρ_j and ρ_{tg}, we consider the transverse dimensions of the colliding jets, having denoted their thickness by $2d$. It will be seen from what follows that this quantity plays the role of a parameter that determines the space scale of the region of spreading of the jets in the vicinity of the plane of their collision.

To describe the motion of the jets, we use a rectangular coordinate system with the x axis in the longitudinal direction and the y axis in the transverse direction (Fig. 2a). As a fundamental hypothesis, we adopt the hypothesis of plane cross sections, i.e., we assume that the motion of each Lagrangian cross section of the jets occurs with preservation of its plane shape, and in any cross section within the limits of the singled-out width $2d$ all the particles of the jets have the same longitudinal velocity v_x, so that $\partial v_x/\partial y = 0$. The hypothesis adopted makes it possible to represent the equation of motion of an arbitrary Lagrangian plane cross section of the jets in the longitudinal direction in the following form:

$$2d\rho \frac{dv_x}{dt} = \frac{\partial F_x}{\partial x}, \tag{4}$$

where ρ is the density of the material in the given cross section ($\rho = \rho_j$ or $\rho = \rho_{tg}$); F_x is the longitudinal force acting in the cross section and referred to unit length (Fig. 2a).

The transverse motion of the particles of the jets in each plane cross section is described by the equation

$$\rho \frac{dv_y}{dt} = -\frac{\partial p}{\partial y}, \tag{5}$$

where p is the pressure acting in the material of the jets.

Defining the rates of deformation of the particles of the jets in the longitudinal and transverse directions as $\dot{\varepsilon}_x = \partial v_x/\partial x$ and $\dot{\varepsilon}_y = \partial v_y/\partial y$ and taking into account the relation $\dot{\varepsilon}_y = -\dot{\varepsilon}_x$ that follows from the condition of incompressibility, we establish linearity of the distribution of the transverse velocity of the particles $v_y = -\dot{\varepsilon}_x y$ over the cross sections with vanishing of this velocity in the plane of symmetry ($y = 0$). With this taken into account, the transverse acceleration of the particles in a Lagrangian plane cross section is represented in the form

$$\frac{dv_y}{dt} = \frac{\partial v_y}{\partial t} + v_y \frac{\partial v_y}{\partial y} = y\left(\dot{\varepsilon}_x^{\,2} - \frac{d\dot{\varepsilon}_x}{dt}\right).$$

Integrating, with account for the last relation, the equation of motion (5) over the transverse coordinate from some current value of it y to the value corresponding to the side boundary of the jets ($y = d$), we find the distribution of pressure in a cross section:

$$p(y) = p(d) + \rho \int_y^d \frac{dv_y}{dt}\, dy = p(d) + \frac{\rho}{2}(d^2 - y^2)\left(\dot{\varepsilon}_x^2 - \frac{d\dot{\varepsilon}_x}{dt}\right). \tag{6}$$

We assume the pressure at $y = d$ to be absent, $p(d) = 0$.

To take into account the electromagnetic forces arising on penetration of the cumulative jet into the target with the magnetic field, the pressure determined by relation (6) is supplemented with the magnetic pressure $p_m = B^2/2\mu_0$ [4]. It was assumed that the magnetic-field induction vector within the limits of the considered width of the jets has a single transverse component $B_y = B$ that is independent of the coordinate y and varies only in the longitudinal direction. Assuming the conductivity of the material to be perfect, the evolution of the magnetic field in different cross sections of the jet that corresponds to the target was described by the relation

$$\frac{dB}{dt} = -\dot{\varepsilon}_x B, \tag{7}$$

which follows from Eq. (1).

With the prescribed distribution of pressure in the cross sections, the longitudinal force entering into Eq. (4) is determined as

$$F_x = 2\int_0^d (p(y) + p_m)\, dy = 2d\left[\frac{1}{3}\rho d^2\left(\dot{\varepsilon}_x^2 - \frac{d\dot{\varepsilon}_x}{dt}\right) + \frac{B^2}{2\mu_0}\right]$$

and the equation of motion of the cross sections of the jets (4) is reduced to the form

$$\rho\frac{dv_x}{dt} = \frac{\partial}{\partial x}\left[\frac{1}{3}\rho d^2\left(\dot{\varepsilon}_x^2 - \frac{d\dot{\varepsilon}_x}{dt}\right) + \frac{B^2}{2\mu_0}\right]. \tag{8}$$

The mathematical description of the model is completed by the kinematic relation

$$\frac{dv_x}{dt} = \int_0^x \frac{d\dot{\varepsilon}_x}{dt}\, dx + \int_0^x \dot{\varepsilon}_x^2 dx, \tag{9}$$

which follows from the condition

$$v_x = \int_0^x \dot{\varepsilon}_x dx + v_x(0),$$

where the longitudinal velocity of the cross section with the coordinate $x = 0$ was set equal to zero ($v_x(0) = 0$), since the origin of coordinates was selected in the target at a sufficient distance from the boundary of contact with the cumulative jet (Fig. 2a).

At the initial instant of time $t = 0$ the parameters of the motion of the colliding jets were prescribed as follows (Fig. 2b). The velocity of the plane of contact of the target with the cumulative jet u_p was assumed to obey the hydrodynamic theory of penetration [5]:

$$u_{p0} = \frac{v_0}{1 + \sqrt{\rho_{tan}/\rho_j}}, \tag{10}$$

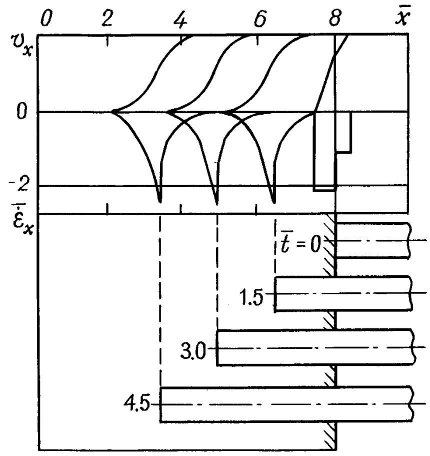

Fig. 3. Distribution of the parameters in the region of interaction in penetration of a copper cumulative jet into an aluminum target in the absence of a magnetic field.

where v_0 is the velocity of the cumulative jet. With distance from the boundary of contact the velocity in the cumulative jet was prescribed to be linearly increasing over the portion l_j from u_{p0} to v_0 and the velocity in the target to be linearly decreasing over the portion l_{tg} from u_{p0} to zero. With the adopted distribution of the velocities of motion over the length of the colliding jets the rates of their longitudinal deformation were different from zero only in the vicinity of the boundary of contact, where they were equal to $\dot{\varepsilon}_x = -u_{p0}/l_{tg}$ in the target and $\dot{\varepsilon}_x = -(v_0 - u_{p0})/l_j$ in the cumulative jet. In modeling penetration with compression of the magnetic field, the field induction B_0 at the initial instant of time was prescribed to be uniformly distributed over the length of the target; in the material of the cumulative jet the magnetic field was assumed to be absent during the entire process of penetration.

In numerical solution of the system of equations (7)-(9) the difference scheme that approximated them was similar to that used in [6]. In the course of the calculations, periodic rearrangement of the difference grid was made in view of the substantial nonuniformity of the deformation of different portions of the jets, which is associated with localization of deformations in the region of their contact.

Calculation Results: Effect of the Compression of the Magnetic Field in the Target on the Dynamics of Penetration of the Cumulative Jet. In analyzing calculation results, it is convenient to use, as a length scale, the prescribed width of the jets $2d$ and, as a time scale, the time of penetration to a depth $2d$ with the velocity u_{p0} of (10) following from the hydrodynamic theory. With this taken into account, in the sequel we will define the dimensionless coordinate as $\bar{x} = x/2d$ and the dimensionless time as $\bar{t} = tu_{p0}/2d$. We will use the dimensionless quantity $\bar{\dot{\varepsilon}}_x = 2d\dot{\varepsilon}_x/u_{p0}$ to characterize the longitudinal rate of deformation of the cumulative jet and the target.

The results obtained on the basis of the described model with a cumulative jet moving in a target without a magnetic field actually reproduce the hydrodynamic theory of penetration. The velocity of the boundary of contact of the cumulative jet and the target u_p remains invariable and equal to the value u_{p0} of (10) throughout the process of interaction. The possibility of determining the character of the deformation of the jets in the transition region is a supplement to the hydrodynamic theory, in which at the boundary of contact of the colliding jets discontinuity of the parameters of their motion occurs. Figure 3 illustrates the penetration of a copper cumulative jet moving with a velocity v_0 = 4 km/sec into an aluminum target. As is seen, for different times of the distribution of the longitudinal rate of deformation the response of the materials of the cumulative jet and the target with their spreading in the transverse direction occurs in narrow layers whose thickness is close to the half-width of the jets d. This result agrees with the theory of the collision of jets, from which, based on the law of conservation of mass, a double decrease in the thickness of plane jets in their spreading at a right angle follows. It should be noted that irrespective of the prescribed initial dimension of the region of localization of deformations (l_j for the cumulative jet and l_{tg} for the target, Fig. 2b), after a certain small time

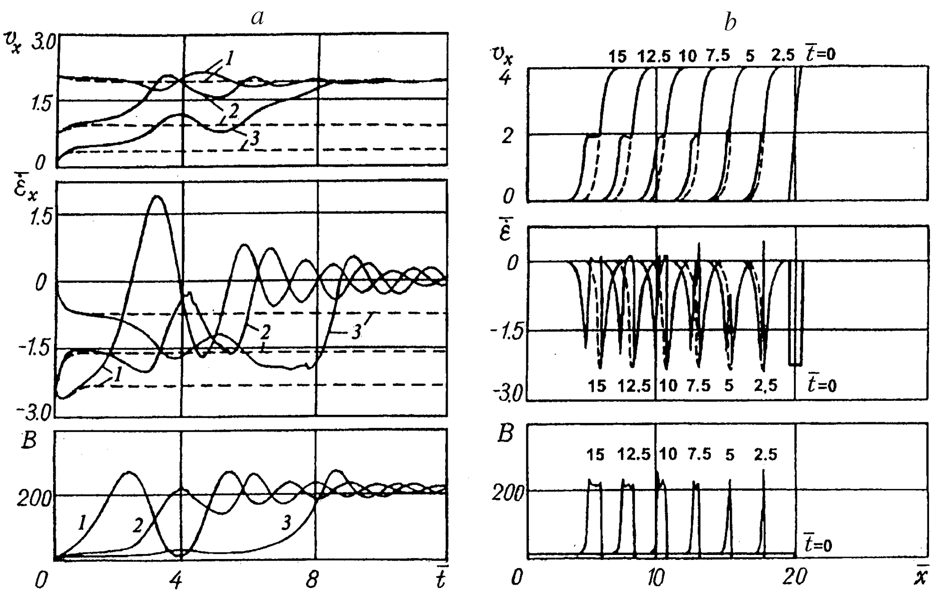

Fig. 4. Specific features of the flow in penetration of a copper cumulative jet into a copper target in the absence (dashed lines) and in the presence (solid lines) of a magnetic field in the target: a) change in the parameters at calculation points 1, 2, and 3 in the target; b) distribution of the parameters over the length of the target and the jet at different instants of time. v_x, km/sec; B, T.

interval the same (under the given conditions of interaction) distribution of the longitudinal rate of deformation along the length of the jets is established, which thereafter remains unchanged.

In simulation of the penetration of a cumulative jet into a target with a magnetic field the distributions (along the length of the interacting jets) of the parameters of their motion and the change in these parameters at fixed calculation points of the target were analyzed. One of these points was located at the boundary of contact with the cumulative jet (1, Fig. 2b) and the other two in the depth of the target at invariable distances $l_1 = 0.25d$ and $l_2 = 0.5d$ from the boundary of contact (2 and 3, Fig. 2b). It is evident that point 1 was constantly associated with the same individual particle of the target, while different particles corresponded to points 2 and 3 during penetration.

Figure 4 illustrates the motion of a copper cumulative jet that has a velocity $v_0 = 4$ km/sec in a copper target for an initial intensity of the magnetic field $B_0 = 10$ T (the dashed lines in this figure correspond to the case of penetration in the absence of a field). The changes in the velocity of motion, the rate of deformation, and the induction of the magnetic field presented in Fig. 4a clearly indicate a tendency toward leveling of all the parameters at the computational points as the penetration progresses. This leveling is accompanied by an oscillatory process in the course of which the velocities of the target points considered tend to the hydrodynamic value of the velocity of penetration u_{p0} of (10). The rates of deformation, changing sign periodically, progress toward a zero value, while the induction of the compressed magnetic field stabilizes at a level of about 220 T. We note that in the particles of the target with magnetic-field compression, passage from deformations of compression in the longitudinal direction to tensile deformations can occur.

The noted character of the evolution of the parameters of motion at the computational points is associated with formation of a "rigid core," i.e., a nondeformable region moving as an entity, in the target directly at the boundary of contact with the cumulative jet. This is demonstrated more vividly by the distributions of the parameters along the length of the jets shown in Fig. 4b. As the penetration progresses, the thickness of the "rigid core" increases continuously in connection with gradual attachment of increasingly new layers of the target to it.

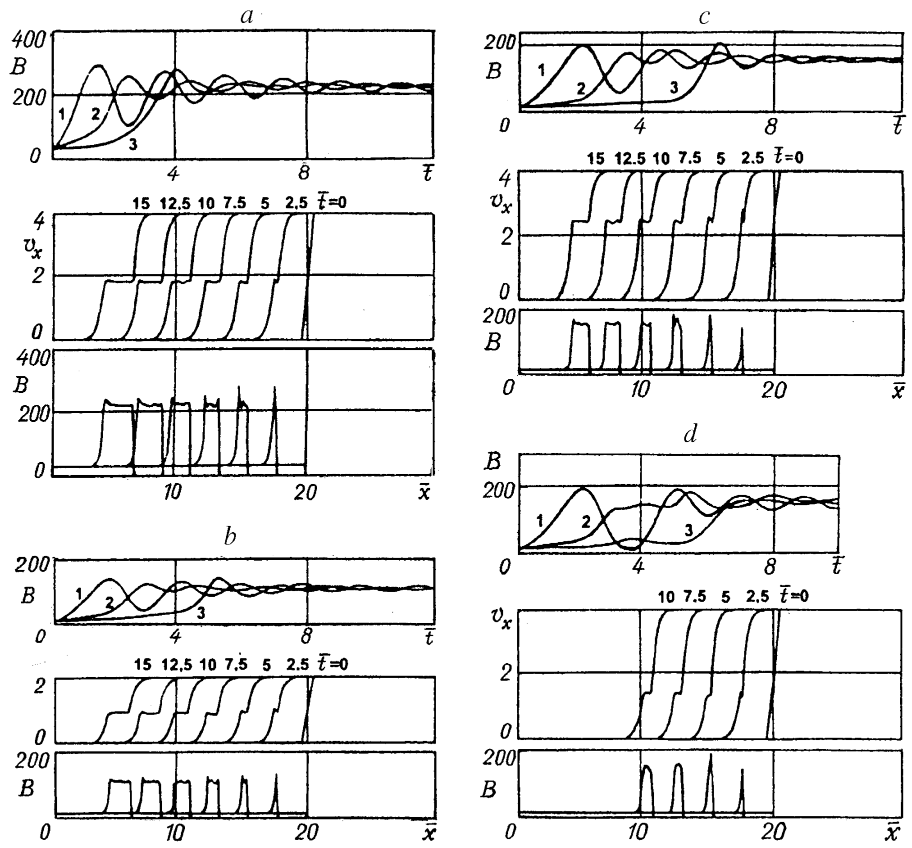

Fig. 5. Specific features of the penetration of a cumulative jet into a conducting target with a magnetic field under different conditions of interaction: a) copper jet and target, v_0 = 4 km/sec, B_0 = 30 T; b) copper jet and target, v_0 = 2 km/sec, B_0 = 10 T; c) a copper jet and an aluminum target, v_0 = 4 km/sec, B_0 = 10 T; d) an aluminum jet and a copper target, v_0 = 4 km/sec, B_0 = 10 T.

The physical mechanism of formation of the "rigid core" in the target is rather clear. Compression of the magnetic field occurs in the process of penetration, first, in the immediate vicinity of the boundary of contact with the cumulative jet, where deformations are localized. The strengthening of the field in this region is accompanied by the appearance and growth of electromagnetic forces that expand the material of the target. When these forces attain a certain value, the particles of the target at the boundary of contact with the cumulative jet lose their capacity for further deformations (for compression in the longitudinal direction and extension in the transverse one), and the increase in the intensity of the field in them ceases. Moving as an entity, they begin to deform the next layers of the target, into which the region of compression of the field also moves. Here, because of the inertial properties of the material of the target, the magnetic field in its particles is "pumped" to a level at which the electromagnetic forces that appear exceed the hydrodynamic pressure that acts in the process of penetration. As a result, the layers of the target where this occurs begin to expand in the longitudinal direction, which is the reason for the appearance of the oscillatory process.

Calculations carried out with variation of the velocity of motion of the cumulative jet v_0 and of the intensities of the initial magnetic field in the target B_0 for different pairs of materials of the cumulative jet and the target (copper and aluminum) showed that qualitatively the picture of penetration with formation of a non-deformable region ahead of the cumulative jet remains unchanged in all cases (Fig. 5). Only the rate of growth of the "frozen" portion of the target and the intensity of the magnetic field attained in it changed. It turned out that the magnitude of the magnetic induction B_{lim} that is established in the "rigid core" after damping of the oscillations corresponds to the intensity of the field that provides equality of the hydrodynamic and magnetic pressures at the boundary of contact of the cumulative jet and the target:

$$\frac{\rho_j (v_0 - u_p)^2}{2} = \frac{B_{\lim}^2}{2\mu_0} . \tag{11}$$

Taking into account that the velocity of penetration u_p differs little from the value u_{p0} of (10) throughout the process, to calculate the maximum attainable induction of the magnetic field in the region of compression we obtain

$$B_{\lim} = \frac{v_0 \sqrt{\mu_0 \rho_j \rho_{\tan}}}{\sqrt{\rho_j} + \sqrt{\rho_{\tan}}} .$$

Thus, the force action of the magnetic field imposes limitations on the extent of its compression. Increase in the field intensity in the target occurs only in the initial stage of penetration of the cumulative jet, and thereafter the motion of the cumulative jet leads only to an increase in the dimensions of the region where the intensity of the field attained its limiting value.

The special feature of motion of a cumulative jet in a target with a magnetic field, predicted within the framework of the model considered, that consists in formation (ahead of the jet) of a continuously increasing "ballast" mass of the "rigid core" virtually affects in no way the velocity of penetration, which invariably remains at the level of its hydrodynamic value (10). It seems that this is due to the fact that in the jet model used the conditions of deformation of deep and face layers of the target are completely identical. Therefore, the translation of the region of localization of deformations into the depth of the target that occurs as the "rigid core" forms actually changes nothing in the conditions of the cumulative-jet motion.

Apparently, under actual conditions formation of a nondeformable region ahead of the cumulative jet must be accompanied by a decrease in the penetration velocity u_p, since deformation of deep layers of the target that are at a distance from the boundary of contact with the cumulative jet is hindered by the need to displace considerable additional amounts of the material. According to condition (11), the increase in the hydrodynamic pressure of the cumulative jet on the target occurring on decrease of the penetration velocity can lead to a still greater increase in the intensity of the magnetic field in the compression region ahead of the cumulative jet. In the limiting case of complete cessation of penetration, the magnetic induction in the target is limited by the value $B_{\lim} = v_0 \sqrt{\mu_0 \rho_j}$, which in a first approximation gives the absolute limit of the growth of the field intensity.

The change in the mechanism of penetration observed on enhancement of the field compressed by the jet to a level of several hundred teslas creates prerequisites for a decrease in the piercing power of a cumulative jet in its interaction with "magnetized" conducting materials.

NOTATION

B, vector of the magnetic field induction; **v**, vector of the velocity of motion of the medium particles; t, x, y, time and space coordinates; ρ, density; ρ_{tg} and ρ_j, densities of the materials of the target and the jet; η, specific resistance of the medium; μ_0, magnetic constant; d_0, thickness of the deformed layer of the target; u_p, penetration velocity; u_{p0}, hydrodynamic velocity of penetration; v_0, velocity of the cumulative jet; v_x and v_y, longitudinal and transverse velocity components; $\dot{\varepsilon}_x$ and $\dot{\varepsilon}_y$, longitudinal and transverse rates of deformation; B_y, transverse component of the magnetic induction; B_0 and B, initial and current induction of the magnetic field; $B_{\lim}$, limiting value of the magnetic induction; L, depth of penetration of the striker; τ_g and τ_d, characteristic times of generation and diffusion of the magnetic field; κ, dimensionless parameter that characterizes the ratio between the rates of generation and diffusion of the magnetic field; ρ_m, magnetic pressure; F_x, longitudinal force; d, half-width of the colliding jets; l_{tg} and l_j, initial length of the deformation portions of the target and the cumulative jet; $\bar{t}$ and $\bar{x}$, dimensionless time and longitudinal coordinate; $\bar{\varepsilon}_x$, dimensionless longitudinal rate of deformation; l_1 and l_2, distance of the calculation points in the target from the boundary of contact with the jet. Subscripts: p, penetration; j, jet; tg, target.

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