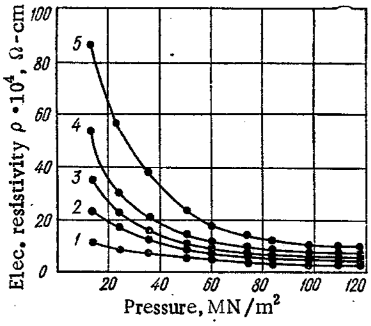

Fig. 6. Variation of electrical resistivity with pressing pressure for various iron powder fractions: 2) +0.16−0.25; 3) +0.10−0.16; 4) +0.05−0.10; 5) −0.05 mm; 1) PZh1S powder (Table 1).

Thus, the electrical resistivity of cold-pressed compacts from iron−ferrochromium mixtures can be decreased by varying the ferrochromium content of the latter, raising the pressing pressure, and using mixtures containing particles of various sizes.

The electrical resistivity of compacts from the US-25 alloy powder pressed cold under pressures of 13 MN/m^2 (130 kgf/cm^2) and higher did not exceed 10^{-4} Ω-cm.

CONCLUSIONS

1. The length of the cold-pressing stage in the EPSP process can be limited to 1 sec.

2. The initial level of cold compact density and electrical conductivity required in the EPSP process can be reached at pressures above 13 MN/m^2 (130 kgf/cm^2) with iron, ferrochromium, and US-25 alloy powders and at pressures above 25 MN/m^2 (250 kgf/cm^2) with iron−ferrochromium mixtures containing 20% or more of the latter component.

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EFFECT OF INTERMOLECULAR AND ELECTROSTATIC COHESIVE FORCES ON THE PROCESS OF DENSIFICATION OF PARTICULATE MATERIALS

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In order to be able to exercise control over the process of cold welding between the particles of a powdered material and alter its direction as may be required, it is necessary to know the quantitative and qualitative laws governing its initiation and development and its dependence on various factors. One of the more important factors determining the intensity of cold welding between metal particles rubbing against each other is the presence of strong electrostatic fields.

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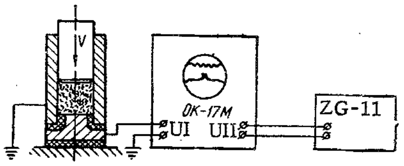

Fig. 1. Diagram of circuit for measuring electrical phenomena in shavings subjected to impulse load.

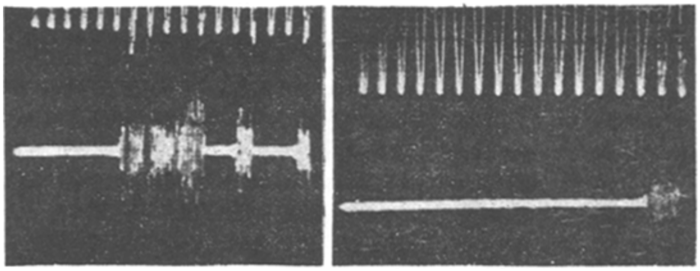

Fig. 2. Typical oscillograms of potential variation in shavings during shock.

To the category of intermolecular and electrostatic cohesive forces belong, e.g., attractive forces, which are one of the causes of instantaneous adhesion in the formation of a dense solid. These forces have a very short range of action. They account for the attraction of gas or vapor molecules in adsorption and of solids in adhesion. Intermolecular forces are generally considered to be Van der Waals' forces, which have been correctly described from a technical standpoint only for nonmetallic materials. Nevertheless, with metals and certain ionic materials, too, a deficiency or excess of electrons on particles produces an increase of electrostatic force fields.

Solids usually react in a complex manner to the application of force impulses. During friction an additional complication arises as a result of the fact that rubbing surfaces are in discrete contact with each other, involving individual micro- and macroirregularities of the surface layers and their structural groups. During their relative motion rubbing surfaces experience, in varying degrees, simultaneous pulse-like compression with shear. This process, as is shown by the experiment described below, takes place in an electric field and is accompanied by electric discharges in individual particles and structural groups of of particles; the potentials of the rubbing parts – elements of the particulate material – exhibit high-frequency pulse-like fluctuations.

The main unit of the apparatus used in the present work for studying electrical phenomena in metal shavings subjected to an impulse load (Fig. 1) was a gunpowder impact tester with a special insulated tool. The signal from a thrust support, which was in contact with shavings, was fed to the input of a modified OK-17M double-trace oscillograph. Diagrams of potential variation as a function of time were photographed on high-sensitivity film from the oscillograph screen. The measuring circuit was calibrated by applying various potentials and measuring the deflections of the oscillograph beam, so as to obtain a grid of values and enable accurate potential measurements to be made during impulse loading. A special check was made with the gunpowder tester without shavings to ascertain that no electromagnetic noise was picked up by the circuit from any parts with residual magnetism. No signals whatsoever were detected by the recording oscillograph in the measuring circuit. Single oscillograph scanning was employed. Scanning was positively initiated before the deformation process with a special contact pickup. To the second channel of the oscillograph was fed an alternating voltage from a ZG-11 generator to obtain a recorded time scale.

Oscillograms obtained (Fig. 2) show that the application of a shock is accompanied by an instantaneous change in potential whose magnitude attains 6.5 MV. The presence of pulse-like high-frequency potential fluctuations is evidence for the existence, on the one hand, of continually operating electrical discharges on the friction surface and, on the other hand, of a source continually producing electrical discharges. The duration of these electrical pulses lies in the range 20-37 μsec.

Let us examine the action of intermolecular forces. As adhesion depends on the character of the contact surface, rough surfaces ensure only limited adhesion, proportional to the true area of contact, even when the adhesive force is very large. When the possibility exists of easily increasing the true area of contact between surfaces, as is the case, for example, in the pressing of waxes and clays, the magnitude of adhesion substantially grows. A wax has very small surface energy, but, because of the above-mentioned effect, wax surfaces can readily be joined together at room temperature. The majority of the strengthening materials, such as ceramic oxides, have very large surface energy, but are very difficult to compact owing to their high resistance to deformation.

In a general form an important equation for calculating the rupture resistance of a compact is [2, 3]

$$\sigma_p = \frac{9}{8}\frac{1-V}{\pi d^2} K P_c, \tag{1}$$

where σ_p is the rupture resistance of the compact; V, volume of the void fraction; K, coordination number; d, particle diameter; and P_c, cohesive force at a point contact. The coordination number K, which depends on the porosity and the product KV, can assume a value approximately equal to 3.1 or π. The quantities d and V can be calculated by analyzing size distribution and packing density.

An expression for determining the cohesive force between two spheres of diameter d placed at a distance a from each other, where $a < 1000$ Å, may be written [2, 3]

$$P_c = \frac{A}{24}\frac{d}{a^2}. \tag{2}$$

Here A, a constant depending on the properties of the material of the spheres, has a value of 10^{-13}-10^{-12} ergs. In a general case Eq. (2) can be replaced by an equation for the approximate calculation of the tensile stress σ_{VW} generated by Van der Waals' forces,

$$\sigma_{VW} = \frac{9}{8}\frac{1-V}{\pi}\frac{A\cdot K}{24a^2 d}. \tag{3}$$

A similar expression can be derived, using Coulomb's law, for the evaluation of electrostatic forces [1, 2],

$$\sigma_e = \frac{9}{8}\frac{1-V}{V}\frac{3\rho_s}{\left(1+\frac{a}{d}\right)^2}, \tag{4}$$

where σ_e is the tensile stress set up by electrostatic forces and ρ_s is the surface change in density.

It is reasonable to assume that the addition of fine particles to a compact brings about more effective filling of voids between the particles of the powdered material and increases adhesion between these particles. Lubricating substances decrease adhesion per unit area, but substantially increase the total area of contact, resulting in stronger adhesion. Nevertheless, it should be noted that the presence of lubricant layers on metals inevitably reduces the number of solid bonds due to the internal pressure in the system. Thus, pure contacts must be provided between particles if effective cold-welding points are to be obtained.

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