CERTAIN REGULARITIES OF PRESSING
TWO-COMPONENT CERMET MATERIALS

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Considerable attention has been devoted in the literature of recent years [2-6] to the development of a theory of compacting powders. An analysis of the known regularities [1, 4-11], shows that the expressions derived describe with insufficient accuracy the relationship between the compacting pressure and the density of the compact. This is because the authors of these works did not take into account the effect of the size and shape of particles, the degree of their workhardening and state of oxidation of the powder, quantity and composition of the lubricant. It should be pointed out that the known regularities were obtained from a study of the processes of compressing one component materials, whereas the effect of a second component has not been studied at all.

In this work, we studied the compactability of materials on a base of reduced iron powder PZh-2M (GOST 9849-61) containing 0.5, 1.0, 2.0, 3.0, 5.0, 7.0, 10.0, and 12.0 mass % glass of brand VVS. For comparison we studied the compactability of materials iron-chromium carbide and iron-chromium (electrolytic) containing 1 and 7 mass % respectively of chromium carbide and chromium. The materials used were; chromium carbide Cr2C3 produced at the Institute of Problems of Materials Science, Ukraine Academy of Sciences, powder of electrolytic chrome and glass powder from culler ground in a ball mill with uranite balls. The chemical composition of the powders was as follows (mass %): iron powder: Fe\text{total}--98.7, C\text{total}--0.10, Mn--0.37, Si--0.20, S--0.02, P--0.02; glass VVS SiO\text{2}--71.4, Al2O\text{3}--1.2, CaO--5.3, MgO--3.3, Na2O--16.8. The grain-size distribution of the iron powder is shown in the table.

The batch was prepared by accurate weighing and thorough mixing of the components without a lubricant. Samples were weighed within an accuracy of ±10 mg. The weight of the samples was calculated on the assumption that when producing a pore-free material not containing a second component, the height of the compact would be equal to its diameter. Compaction (bilateral) was done in a steel mold 12 mm in diameter with the walls of the mold being lubricated with machine oil before pouring the weighed samples. The pressure of compaction varied from 11 to 90 kg/mm\textsuperscript{2}. Compression in the pressure range of 11-30 kg/mm\textsuperscript{2} was done on a mechanical press with a force of 10 t within an accuracy of ±10 kg/cm\textsuperscript{2}, and at a higher pressure on a hydraulic press with a force of 100 t within an accuracy of ±100 kg/cm\textsuperscript{2}. The rate of compression in all cases was 30 mm/min. Ten compacts of each composition were pressed at the same pressure. They were weighed on an analytical balance and measured with a micrometer.

The results of the investigation of the above-indicated materials are shown in Fig. 1. We see from the graph that as the glass content increases the relative density of the metal skeleton decreases; the dependence of porosity on the glass content and pressure has a more complex character: at a compaction pressure below 30 kg/mm\textsuperscript{2}, the porosity decreases with an increase of glass content and at a higher compaction pressure it increases. Apparently,

| Grain-Size Distribution of Iron and Glass Powders |
|------------------------------|------------------------------|
| Fractions | Powder |
| +0.160--0.250 | +0.160--0.160 | +0.080--0.100 | +0.056--0.080 | +0.056--0.056 |
| Iron | 1.70 | 29.70 | 41.50 | 14.47 | 14.00 |
| Glass | 11.60 | 12.30 | 14.00 | 11.02 | 25.42 |

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a pressure of 30 kg/mm$^2$ is critical; at a lower pressure compaction proceeds mainly by slip of the particles relative to each other and the introduction of glass promotes the formation of a denser compact. At a compaction pressure greater than the critical, compaction proceeds mainly by plastic deformation and, since glass has a very low deformability, its introduction into the composition of the batch promotes the formation of a less dense compact (i.e., compactability deteriorates). The dependence of the density of compacts on compaction pressure is shown in Fig. 2, from where it follows that, with an increase of the glass content the density of the compacts decreases (at a constant pressure), but the over-all shape of the dependence is retained for all investigated metal-glass materials. We see from Fig. 3, that when glass is added to the composition of the batch the density of the compact (at a constant pressure) diminishes almost linearly.

In describing processes of compacting we must frequently use the relationships proposed by M. Yu. Bal'shin[1]

\[
\lg P = L (\beta - 1) + \lg P_{\text{max}},
\]

\[
\lg P = - m \lg \beta + \lg P_{\text{max}},
\]

where L is a factor of compression; $\beta$ is the relative volume; $P_{\text{max}}$ is the pressure necessary to produce a pore-free compact; m is a constant.

It was shown in the work of one of the authors [3], that the equations of Konopicky [7], Torre [8], Rutkowski and Rutkowski [9], Smith [10], Agte and Petrdlik [11] can be reduced to the form of Eq. (2). An analogous conclusion can be made after analyzing the equation of A. N. Nikolaev [6], G. A. Meerson [2], derived Eq. (2) by three methods which also indicates its reliability.

The dependence of the density of the iron-glass, iron-chromium carbide, and iron-chromium materials on compression pressure in logarithmic coordinates is shown in Fig. 4. We see from the graph that the indicated dependence has a linear character:

\[
\lg \gamma = n (\lg P - \lg P_\tau) + \lg \gamma_\tau,
\]

![Diagram](image)