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EFFECT OF ADDITIONS OF COPPER ON THE STRENGTH PROPERTIES OF SINTERED METAL–GLASS MATERIALS AND METHOD OF ITS INTRODUCTION

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Many friction units of machines used in the chemical, textile, and food industries operate in the media being processed. The simultaneous action of corrosive media and mechanical loads sharply intensifies their wear. Among such units are journal bearings working in alkali solutions (e.g., immersion bearings of tanks of cloth mercerization lines). Journal bearings made of metal–glass materials consisting mainly of iron, graphite, and glass are often successfully used under such conditions.

The wear resistance of metal–glass materials in operation involving rubbing in alkali solutions is 2.5-3 times higher than that of the standard ZhGr3 material.* However, the ductility of metal–glass materials is much poorer than that of iron–graphite composites. The physicomechanical properties of such sintered materials can be improved by adding to them various alloying elements. One of them is copper [1-3]. The addition of copper in an amount equal to 1-4% of the weight of the charge increases the strength and wear resistance of iron–graphite materials [2, 3].

It is usual to add alloying elements in powder form to the charge and then thoroughly mix them together with the remaining components. To shorten charge mixing time while ensuring that the charge components are evenly distributed throughout the pressed part, alloying can be effected by chemical reduction of the alloying element (such as copper) on the particles of one of the powder components [4].

Below are presented the results of an investigation of some properties of metal–glass materials alloyed with copper. Copper was added to the materials by two methods: 1) in powder form direct to the charge; 2) chemical deposition on glass powder particles, the copper-coated powder being then added to the charge. The process of chemical deposition of copper on VVS glass powder consisted of the following operations: degreasing of the powder surface, sensitization, activation, and reduction of metallic copper [5].

The starting materials were PZh2M iron powder to GOST 9849-61, ÉUG-II graphite to GOST 10274-62, PM2 copper powder to GOST 4960-68, and a glass powder produced by grinding broken VVS sheet-grade glass. Test specimens were pressed under a pressure of 6.5 tons/cm^2 and sintered for 1.5 h in a hydrogen atmosphere at a temperature of 1100-1110°C. The materials obtained had a ferritopearlitic structure. Data on the strength properties of the materials investigated are given in Table 1.

*A sintered material produced from a charge consisting of iron with a 3 wt.% graphite addition. Also referred to in this article are PZh2M, a fine reduced iron powder of 98.0% minimum purity, and VVS, an $SiO_2-Na_2O-CaO-MgO-Al_2O_3$ sheet-grade glass – Translator.

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TABLE 1. Strength Properties of Metal–Glass Materials Investigated

Material	Composition of sintered material,	Hardness HB	Impact str., kgf-m/cm^2	Compr. str., kgf/cm^2	Porosity, %
Unalloyed (for comparison)	Graphite 3 Iron 97	55—70	0,30—0,35	45—60	25—30
	Graphite 3 Molybdenum disulfide 2 Glass 7 Iron 88	55—69	0,10—0,15	20—27	26—32
With Cu-coated glass powder	Graphite 3 Cu-coated glass 7.8 Iron 89.2	96—105	0,23—0,27	57—62	17—19
	Graphite 3 Cu-coated glass 9 Iron 88	100—112	0,22—0,28	55—60	18—19
	Graphite 3 Cu-coated glass 10 Iron 87	117—124	0,28—0,31	60—62	18—19
With Cu and glass in powder form	Graphite 3 VVS glass 7 Copper 0.8 Iron 89.2	84—92	0,21—0,25	46—50	17—19
	Graphite 3 VVS glass 7 Copper 2 Iron 88	85—97	0,2—0,25	48—54	18—19
	Graphite 3 VVS glass 7 Copper 3 Iron 87	113—120	0,24—0,27	56—58	18—19

All the materials with copper-coated glass contained 7 wt.% of glass.

TABLE 2. Coefficients of Pair Correlation between Properties (hardness HB, impact strength a_k, and compressive strength σ_c) of Materials Investigated

Property	HB	a_k	σ_c
HB	1	0,88	0,943
a_k		1	0,861
σ_c			1

It is known that at sintering temperatures above 1100°C copper added to an iron matrix diffuses into it, thereby appreciably increasing its strength and hardness [2]. From Table 1 it can be seen that even small additions of copper (0.8 wt.%) increase the hardness of metal–glass materials by 50–80% and at the same time improve their ductility. The strength properties of sintered materials alloyed with copper-coated glass are higher than those of similar materials alloyed with glass and copper powders. The reason for this is that copper reduced on the comparatively large surface of the glass powder is evenly distributed in the charge and can therefore effectively stabilize the structure of the material.

Statistical relationships between the strength characteristics investigated were established by correlation analysis. Using experimental data, coefficients of pair correlation were determined with the formula

$$r = \frac{\sum_{u=1}^{n} (y_{1u} - \bar{y}_1)(y_{2u} - \bar{y}_2)}{\sqrt{\sum_{u=1}^{n} (y_{1u} - \bar{y}_1)^2 (y_{2u} - \bar{y}_2)^2}},$$

where y_1 is one of the properties of the materials investigated (e.g., Brinell hardness HB), y_2 another property of the materials (e.g., impact strength a_k), n the total number of experiments, u the serial number of a given experiment,

$$\bar{y}_1 = \frac{\sum_{u=1}^{n} y_{1u}}{n}, \text{ and } \bar{y}_2 = \frac{\sum_{u=1}^{n} y_{2u}}{n}.$$

The coefficients of pair correlation between the properties are given in Table 2. All the coefficients of pair correlation are statistically significant because, at the chosen level of significance $a = 0.05$ and the number of degrees of freedom f = 7, the critical value of coefficient of correlation ($r_{cr} = 0.666$) is smaller than the calculated values.

Now the coefficient of pair correlation is a measure of closeness of linear relationship between two properties of a material [6]. It will be seen from Table 2 that the calculated values of coefficients of pair correlation are approximately equal to unity, and consequently the linear relation between pairs of these properties is close. From the positive sign of the coefficients of correlation it can be concluded that with increase in the value of one of a pair of characteristics the value of the other characteristic, too, grows.

A linear relation between the hardness and strength of such a material is possible when any structural changes increase in the dispersion of the pearlite, because the finer the resultant eutectoid mixture the higher are the strength and the hardness [7].

To make it possible to predict the value of any one property from that of another, regression equations were formulated. For a material containing 7.8% of copper-coated glass the regression equations are

$$HB = 40.101 + 233.3a_k; \quad \sigma_c = 2441.3 + 13971.1a_k; \quad a_k = 192.1 + 56.7HB.$$

The equations were tested for accuracy using Fisher's number and found to be statistically significant. Similar relations were obtained for all the other materials investigated.

CONCLUSIONS

1. The addition of copper to metal–glass materials improves their strength characteristics.

2. Particularly effective is the method of alloying of metal–glass materials by chemical reduction of copper on the glass powder particles.

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