The choice of powder charges and properties of the powder composite material "iron-cast iron-glass"

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Abstract. The article discusses the choice of powder charges and the properties of the powder composite material "iron-cast iron-glass", developed a charge for obtaining metal-glass material. The choice of the composition of the material "iron-cast iron-glass" was substantiated by theoretical and experimental methods. With the theoretical substantiation of the composition of the charge, a model was built using FCM clustering of experimental data. In the experimental substantiation of the choice of the composition of the charge, the content of cast iron and glass, as well as the dispersion of their particles, were chosen as parameters for optimization.

The microstructures, mechanical and tribotechnical properties of the materials ЖЧ10С2, ЖЧ20С4 and ЖЧ50С6, pressed at a pressure of 1000 MPa, sintered in a furnace in an endogas environment at a temperature of 1150 ° C, for 2 hours have been investigated.

The dependences of the chemical composition, structure of the metal matrix and glass inclusions, as well as the physicomechanical and tribotechnical properties of sintered powder materials on the degree of dispersion, the content of cast iron and glass powders in the charge have been established.

It was determined that the best complex of properties is possessed by materials containing 50 and 6 wt. %. Of cast iron and glass powders, respectively, with the dispersion of the first - 160 + 100 microns.

Keywords: charge, iron-cast iron-glass, matrix, powder composite material, structure, dispersion, physical-mechanical, tribotechnical properties.

I. INTRODUCTION

In the early 60s, metal-glass materials were created on the basis of powder metallurgy. They have a pronounced heterogeneous structure, their metal base has a microhardness of 5 - 6 GPa, glass inclusions - 10 -11 GPa [1]. The results of the development of a rational technology for obtaining wear resistance of metal-glass materials are given in [2, 3], devoted to the study of the processes of compaction and sintering of iron-glass charges, impregnation of a porous iron frame with a glass melt, as well as destruction and deformation of metal-glass materials.

During sintering, the glass hardness increases, which improves the wear resistance. The strength and ductility of the material is determined by the characteristics of the metal frame, high values of which are achieved only by hot pressing or hot stamping. The complexity of the latter, as well as the complexity of the equipment for their implementation, requires a search for new wear-resistant iron-glass materials with a set of higher technical characteristics when manufactured by cold pressing and sintering.

II. STATEMENT OF THE PROBLEM

For this purpose, to eliminate the disadvantages inherent in known materials, either containing scarce components or having low properties [4], a charge was developed for obtaining a metal-glass material. It contains powder obtained from shavings of gray cast iron produced according to ТУ 16-89 ВАИК 41 1100.006ТУ and containing (wt.%): carbon - 3.0 - 3.8; silicon - 1.5 - 2.8; manganese - 0.5 - 1.0; phosphorus - 0.05 - 0.1; sulfur - 0.05-0.1. The charge is obtained by mixing in a Y-shaped mixer for 2.4 cc iron powders of the grade ПЖ2М3 ГОСТ 9849-74 - 40 - 88 wt.%, Cast iron - 10 - 50 wt.%. And vacuum glass of the C88-5 OST 11027 grade. 037- 79 - 2 - 10 wt.%. The choice of the content of cast iron powder in the range of 10 - 50 wt.%. Is explained by the fact that this range was studied by us in previous materials and is the most suitable from the point of view of the processability of the charge and ensuring sufficiently high properties of the sintered material. The glass content in the charge is recommended not to exceed more than 10 wt.% [5], otherwise its manufacturability and properties of the sintered material deteriorate.

The coefficient of friction and wear of the material was studied under dry friction on a standard СМЦ-2 machine according to the scheme of a prismatic sample - a sleeve made of 45 steel, hardened to a hardness of 50 HRC. The pressure on the sample was constant and amounted to 4.0 MPa at a sliding speed of 1.0 m / s. The samples were pressed under normal conditions under a pressure of 1000 MPa and sintered in endogas at a temperature of 1150 ° C.

The choice of such a high pressing pressure is explained by the poor compressibility of the charge due to glass and cast iron powders [6].

III. SOLUTION OF THE PROBLEM

To improve the interfacial interaction, and, consequently, to increase the mechanical properties and wear resistance, it is necessary to introduce components that have better wettability with it into the charge containing glass. The use of cast iron powder in the composition of the charge can lead to this effect, since cast iron contains a large amount of silicon and manganese, which, during heating in an oxidizing environment, form oxides that are difficult to reduce. It is known that metal oxides are better wetted with each other than pure metals with oxides [7]. It must be assumed that in the process of sintering, silicon and manganese oxides will be well wetted by glass, forming strong bonds. This concept was the basis for the selection of iron, cast iron and glass for composite sintered materials.

The choice of the composition of the material "iron-cast iron-glass" was substantiated by theoretical and experimental methods [8]. When theoretically substantiating the composition of the charge, a model was built using FCM clustering of experimental data to derive the fuzzy IF-THEN rules describing the relationship between material composition and properties. As an example, "iron-cast iron-glass" (Fig. 1).

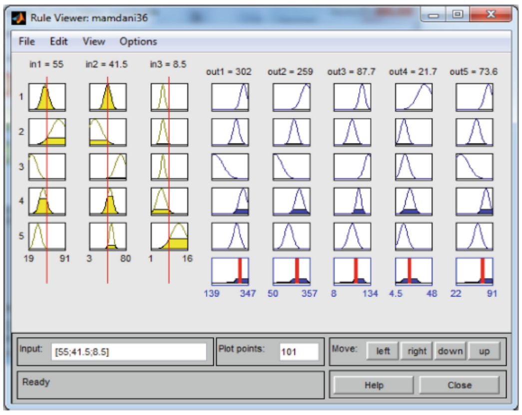


Fig. 1. Graphical description of fuzzy rules

In the experimental substantiation of the choice of the composition of the charge, the content of cast iron and glass, as well as the dispersion of their particles, were chosen as parameters for optimization. The pressing of prismatic samples (55x10x10 mm) was carried out under a pressure of 1000 MPa under normal conditions, and sintering at 1150 ° C in an endothermic gas for 2 hours [9]. As can be seen from Table 1, samples containing 30 - 50 wt.% cast iron with particle sizes from 100 to 160 mcm and 2 - 6 wt.% glass powder (50 - 200 mcm) have the highest mechanical properties.

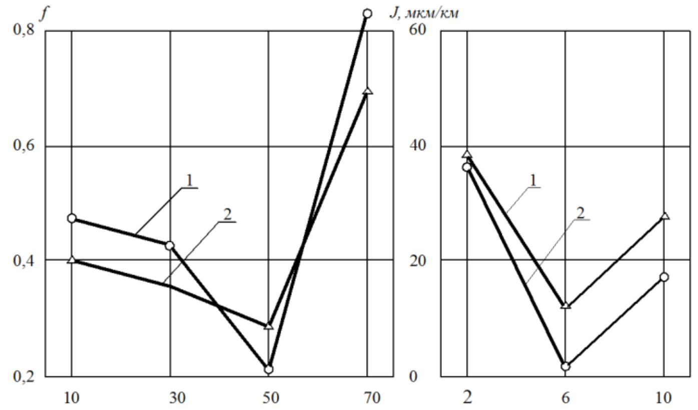
Table 1

Influence of the composition of the charge and the dispersion of cast iron and glass powders on the properties of the sintered material

Powder content, wt%		Dispersion, mcm		Properties after sintering					
cast iron	glass	cast iron	glass	ρ, q/sm^3	Π, %	σ_b, MPa	σ_u, MPa	KC, kJ/m^2	HB, MPa
10	2	-160+100	-200+50	6,10	16,6	134	289	205	720
20	4	-160+100	-200+50	6,20	15,4	227	332	241	950
50	6	-160+100	-200+50	6,40	9,3	298	395	284	1070
70	6	-160+100	-200+50	6,0	16,0	98	180	92	1090
50	10	-160+100	-200+50	6,35	14,4	249	310	119	1020
50	6	-630+400	-200+50	6,3	10,1	200	330	199	1100
50	6	-630+400	-200+50	5,6	20,5	234	281	127	1050
50	6	-400+320	-200+50	5,7	19,5	261	301	193	1090
50	6	-320+200	-200+50	5,6	17,3	136	172	192	1010
50	6	-160+100	-200+50	6,0	14,0	210	329	187	1060
50	6	-160+100	-160+100	6,0	14,6	200	368	160	1030
50	6	-160+100	-100+50	6,0	14,6	190	337	204	1050

Fig. 2 the dependence of f and J on the content of cast iron (a) and glass (b) powders is shown, from which it can be seen that with an increase in the content of cast iron powder in the charge (with a glass powder content of 6 wt.%) from 10 to 50% f and J tend to decrease. Subsequently, they sharply increase, which is associated with the intensification of wear due to the low mechanical properties of the material of this composition. Thus, the best antifriction properties are possessed by a material containing 50 wt.% cast iron, which was used for research.

As can be seen from Fig. 2, b, good antifriction properties are achieved at 6 wt% glass. With an increase in the content of glass powder in the charge up to 10%, the brittleness of the material increases, which leads to the crumbling of solid particles, and hence to abrasive wear. With a decrease, f and J also significantly deteriorate, which is associated with the worse mechanical properties of the material.



Cast iron content, wt.% Glass content, wt.%

Fig. 2. Dependence of f and J of sintered specimens on the content of cast iron (a) and glass (b) in the charge, 1-dry friction coefficient (f); 2- wear rate (J).

Studies were also conducted on the effect of the glass grade. The samples were pressed in a mold using a "sweating" matrix under a pressure of 1000 MPa and sintered at a temperature of 1150 ° C, as follows from those given in Table 2. data, wear-resistant powder material based on iron (compositions 1 - 3) has sufficiently high mechanical and antifriction properties. The use of glass of a different brand (compositions 4,5) in the batch leads to their decrease, which is due to the fact that vacuum glass contains a greater amount of SiO2, MnO, Ba2O3, [10], which are well wetted with iron and cast iron particles, which have a surface oxides. A decrease in the content of cast iron and glass less than 10 and 2%, respectively, leads to a decrease in the mechanical properties of the material, and an increase in their content of more than 50 and 10% makes it difficult to press the powder charge.

Table 2.

Compositions of charges and properties of materials obtained from them

№ composition	Content of components in the charge, wt.%		Glass brand	Cast iron composition, wt.%					Glass powder size, mcm	Cast iron powder size, mcm	Size ratio of cast iron and glass powders	Sintered material properties			
	Cast iron powder	Glass powder		C	Si	Mn	P	S				σ_b, MPa	σ_u, MPa	KC, kJ/m^2	*f*
1	10	2	C88-5	3,8	1,5	0,5	0,05	0,05	10	100	1:0,1	490	1050	125	0,15
2	30	6	C88-5	3,4	2,1	0,75	0,075	0,075	50	150	1:0,3	475	970	116	0,13
3	50	10	C88-5	3,8	2,8	1,0	0,1		100	200	1:0,5	453	907	95	0,14
4	30	6	№40	3,4	2,1	0,75	0,075	0,075	50	150	1:0,3	340	750	78	0,22
5	30	6	№46	3,4	2,1	0,78	0,075	0,075	50	150	1:0,3	350	760	80	0,21

In the process of sintering of the "iron-glass" system, the glass melts, at its interface with the metal, free silica interacts with the metal oxide. Further, the oxides dissolve in the glass and complex compounds are formed - silicates. The main condition in this case is the presence of oxides on the metal surface, the melting point of which should significantly exceed the glass melt temperature.

In the materials of the "iron-iron glass" system, this mechanism proceeds somewhat differently. Since cast iron contains an active reducing agent in the form of graphite inclusions, when heated, there is a danger of removing oxides from the metal surface, and therefore they are not wetted with glass. Therefore, the principle of formation on the surface of dissimilar particles of "related" phases and inclusions, providing their interphase interaction during sintering, is proposed. This principle is realized by conducting steam-thermal oxidation of green blanks. It was found that the difficult-to-reduce oxides SiO_2, MnO and iron oxides formed in this process dissolve well in the glass during sintering. [11] Microstructures of materials ЖЧ10С2, ЖЧ20С4 and ЖЧ50С6 (grades conventionally accepted) pressed at a pressure of 1000 MPa, vapor-oxidized and sintered at 1150 ° C in an endothermic gas for 2 hours. is shown in Fig. 3. and Fig. 4.

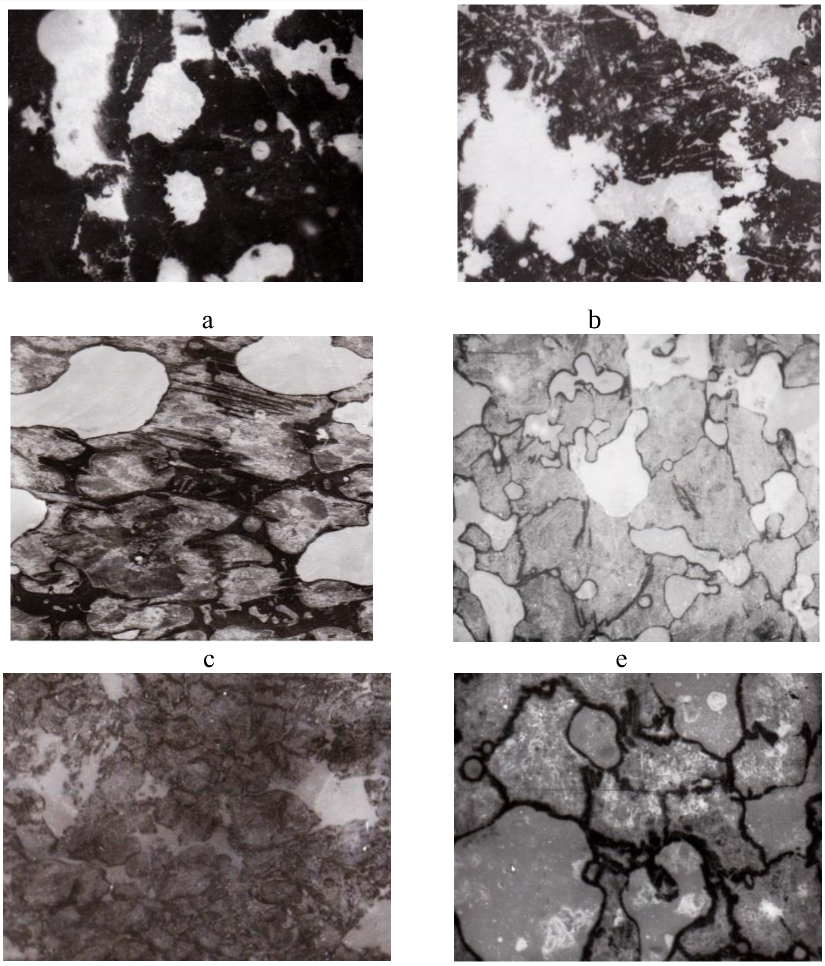
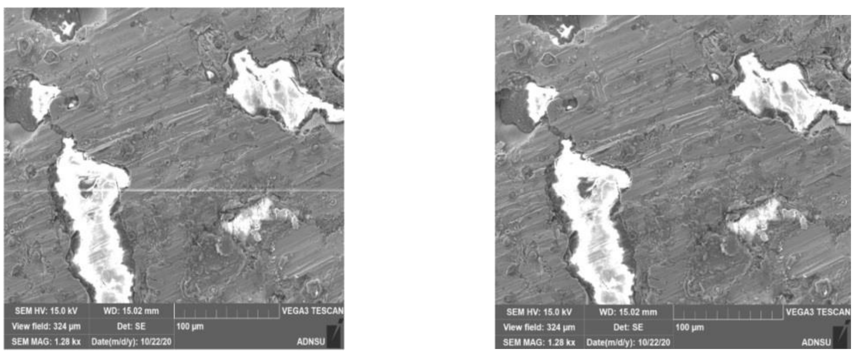
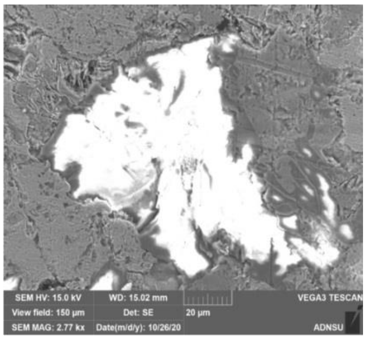


Fig. 3. Microstructure of iron-cast iron-glass, x 400. a, b; c, e; d, v cast iron and glass content 10 and 2; 20 and 4; 50 and 6 wt.%, respectively



a b



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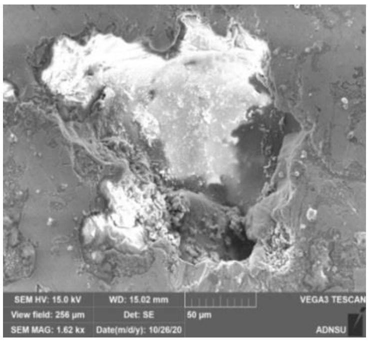

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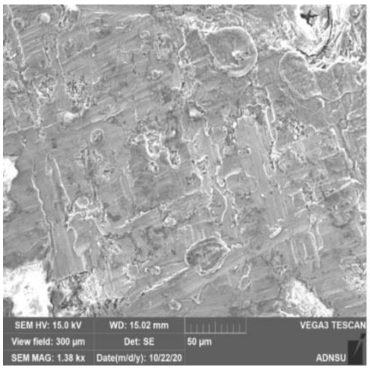

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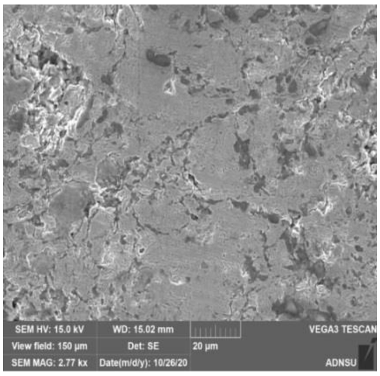

v

Fig. 4 - Distribution of the glass phase in the matrix of the composite material iron-cast iron-glass. a, b; c, e; d, v cast iron and glass content 10 and 2; 20 and 4; 50 and 6 wt.%, respectively

Sintered alloys ЖЧ10С2, ЖЧ20С4 and ЖЧ50С6 have a pronounced heterogeneous structure - a metal matrix and uniformly distributed glass inclusions. The structure of the metal matrix is represented by pearlite and ferrite; structurally free cementite is also observed in the ЖЧ20С6 alloy. Glass particles in the process of sintering changed their shape from fragmentation to more rounded. The first level of heterogeneity is observed between the metal matrix and glass inclusions, the second - in the matrix itself, which contains both hard and soft inclusions (Fig. 4.)

An increase in the content of cast iron and glass powders in the charge from 10 to 50 and from 2 to 6 wt.%. Respectively, (Table 1), also contributes to an increase in the strength of materials. At the same time, if an increase in the content of cast iron, and therefore carbon leads to the enrichment of austenite in the latter, then an increase in glass improves the wettability of the particles of the multicomponent system.

IV. CONCLUSIONS

The choice of the composition of the iron-cast-iron-glass material is theoretically and experimentally substantiated. The highest mechanical properties are exhibited by samples containing 30 - 50 wt.% Cast iron with particle sizes from 100 to 160 microns and 2 - 6 wt.% Glass powder (50 - 200 microns). The microstructures, mechanical and tribotechnical properties of a composite powder material iron-cast iron-glass have been investigated and the dependences of the chemical composition, structure of the metal matrix and glass inclusions, as well as the physical-mechanical and tribotechnical properties of sintered powder materials on the degree of dispersion, the content of cast iron and glass powders in the charge have been established. It was determined that the best set of properties is possessed by materials containing 50 and 6 wt. % of cast iron and glass powders, respectively, with the dispersion of the first -160 + 100 microns.

REFERENCES

[1] V.V.Vasil'ev, V.D.Protasov, *Kompozicionnye materialy*. Moskva, Spravochnik, Mashinostroenie, s. 512, 1990.

[2] O.N.Lyubimova, E.P.Solonenko, *Modelirovanie povedeniya nesoglasovannogo spaya stekla s metallom s uchetom svojstv zony soedineniya*. Fizicheskaya mezomekhanika, t. 19, № 2, s.114–119, 2016.

[3] O.N.Lyubimova, A.V.Morkovin, S.A.Dryuk, P.A.Nikiforova, *Struktura and constitution of glass and steel compound in glass–metal composite* (AIP Conf.Proc № 1623: 2014), pp. 379–382.

[4] T.G.Jabbarov, *Razrabotka Kompozitsionnykh Poroshkovykh Materialov 'Zhelezo–Chugun–Steklo' dlya Detalei Bytovoi Tekhniki* (Novocherkassk: Development of Composite Powder Materials 'Iron–Cast Iron–Glass' for Household Appliance Components: 1992), Disser. for Cand. Tech. Sci., (in Russian).

[5] T. Sinha. A study on the sensitivity of Drucker–Prager Cap model parameters during the decompression phase of powder compaction simulations / T. Sinha // Powder Technology. №198, pp.315–324, 2010.

[6] U. Shigeru. Steel Powder and Die-lubricated Warm Compaction for Automotive Sintered Parts with High Density and Excelent Fatigue Property / U. Shigeru, O. Yukiko, U. Satoshi // JFE Technical report.. No.4, pp. 81-88, 2004.

[7] V.N. Anciferov, I.V.Anciferova, Osobennosti processov spekaniya s ispol'zovaniem nano razmernyh tverdo plavnyh poroshkov (Perm': Vestnik Permskogo nacional'nogo issledovatel'skogo politekhnicheskogo universiteta. Mashinostroenie, materialovedenie. Nauchnyj obzor: 2015), T.2, s.66-77.

[8] *Mustafa Babanli. Theory and Practice of Material Development Under Imperfect Information*. Explore Further: Topics Discussed in This Paper,Computer Science. 2018 (First Publication: 26 August 2018).

[9] Zalazinskij G.A., Polyakov A.A., Polyakov A.P. O plasticheskom szhatii poristogo tela // Izv. RAN. Mekhanika tverdogo tela, № 1, S. 123-134, 2003.

[10] G.A.Libenson, V.YU.Lopatin, G.V. Komarnickij. Processy poroshkovoj metallurgii. T. 2. Formovanie i spekanie. M.: MISIS, 320 s., 2002.

[11] Processy poroshkovoj metallurgii. T.1. uchebnik dlya vuzov / G. A. Libenson, V. YU. Lopatin, G. V.Komarnickij. M.: MISIS, 283 s., 2001.