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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

PROCESSİNG OF İRON-BRONZE AND İRON-BRONZE ALLOY MATERİALS, STUDY OF THEİR STRUCTURE AND PROPERTİES

Specialty: 3312.01– Materials technology

Field of science: Technical sciences

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and degree of development. In the production of details of household appliances, mechanisms and devices, methods of grinding metallurgy are more widely used. These details are of various purposes and are very diverse. Grinding metallurgy methods allow to increase the metal utilization rate and increase labor productivity. At the same time, they lead to an increase in economic efficiency, maximum reduction or complete elimination of mechanical processing.

Wear-resistant details are among the most widely used details made by grinding metallurgy methods. The composition of details made of non-wearing grinding materials is mainly ferrous and non-ferrous metals.

The presence of pores in the structure of these materials contributes to lubrication during friction during the work process. Pores pre-impregnated with oil play the role of oil reservoirs. The oil absorbed into the pores lubricates the counterpart due to "sweating" on the surface during dry friction. As a result, the friction coefficient decreases and the wear resistance of the material increases.

On the other hand, graphite, stearin, talc, etc. are added to the composition of the bearing materials as solid lubricants. This also creates a positive role of these lubricants in the working process. Solid lubricants lubricate the surfaces in contact during the friction process, especially in the absence of a lubricant. In the case of liquid lubricants, they participate in friction by creating a colloidal mixture between the rubbing surfaces and help improve the tribotechnical properties of the material.

Iron and graphite make up the majority of the composition of antifriction bearing materials. When working with a steel counterbody, the friction coefficient of iron-graphite in lubrication is 0,07÷0,09. Iron-graphite bearings are used at a permissible load of not more than 1000-1500 MPa and a maximum temperature of 100-200 °C. Mechanical properties of ferrographite: tensile strength limit σ_d=180-300 MPa, hardness is 600-1200 MPa.

However, the presence of carbon in the composition of ferrographite (carbon in graphite) leads to the formation of cementite during the baking process. This undesirable structural component of ferrographite, mainly in oil-free friction, causes scratching, abrasion of the counterbody and, as a result, macro-adhesion with the pad.

Therefore, other solid lubricants are added to the composition of ferrographite, which in most cases leads to an increase in the cost of the material. On the other hand, some of them, especially sulfur and sulfides, are toxic. Some of them, playing a negative role in the baking process, reduce the mechanical properties of the material and negatively affect the load-bearing capacity.

For this purpose, the creation of new porous antifriction materials obtained from a mixture of ferrous and non-ferrous metal alloys can be considered more important from a scientific and practical point of view. For this purpose, the creation of a new composite material, conventionally called "iron-bronze", from a mixture of iron ore with copper and tin ores in certain proportions, is considered an urgent issue. In this case, the ratio of non-ferrous metal ores to iron ore should be taken in such a way as to ensure economic efficiency and the unity of the necessary tribotechnical characteristics.

By using bronze instead of bronze, a more economically positive solution to the issue can be achieved. That is, a casting charge can be prepared from a mixture of iron and bronze ores in certain proportions. In this case, the problem of bronze ore being more expensive than bronze ore in the charge and, as a result, the price of the final material increases would be eliminated. The obtained casting materials with a new composition can also be conventionally called "iron-bronze".

Thus, it can be noted that the development of new porous casting materials with antifriction purposes, such as "iron-bronze" and "iron-bronze", is a pressing issue. The solution of this issue will further expand the possibilities of cast metallurgy. The development and application of such materials will increase both their economic efficiency and their load-bearing capacity.

The goals and objectives of the research are to develop new porous cast materials of the "iron-bronze" and "iron-bronze" types, and to study the interaction between their composition, structure and properties.

To achieve this goal, the following tasks were set:

- selection and justification of new alloy compositions consisting of "iron-bronze" and "iron-bronze";
- study of the structure, mechanical and tribotechnical properties of "iron-bronze" and "iron-bronze" heterogeneous alloy materials obtained by cold pressing and subsequent annealing;
- determination of the phase compositions of the structural components formed after annealing in the processed materials;
- evaluation of the behavior and tribotechnical properties of "iron-bronze" and "iron-bronze" materials under various friction conditions;
- determination of the characteristics and development directions of the relationships between the composition and properties of materials using a computer;
- development of recommendations for the application of the obtained results in production and attempts to implement their application.

Research methods. The issues set in this work were resolved on the basis of theoretical and experimental studies conducted in laboratory and production conditions. Computer technology was used in the processing of the experiments and the extraction of analytical expressions.

The accuracy of the results obtained was confirmed by experimental studies using modern devices, measuring instruments, equipment and accessories.

The main provisions put forward for defense:

1. Basic provisions for the synthesis of “iron-bronze” and “iron-bronze” antifrictional coating materials;
2. Criteria for evaluating the tribotechnical properties of “iron-bronze” and “iron-bronze” coating materials;
3. Explanation of the processes occurring in the pressing of a ferrous-non-ferrous metal coating charge mixture;
4. Kinetics of the firing of “iron-bronze” and “iron-bronze” coating materials;

5. Explanation of the structural transformation of fired iron-bronze and iron-bronze coating materials.

Scientific novelty of the research. The influence of anomalous high content of plastic components - copper, tin, bronze and talc in the melt on the formation of the structure, physical-mechanical and tribotechnical properties of iron-based compositional fired materials has been determined.

The mechanism of structuring in the firing process of iron-bronze and iron-bronze containing a solid lubricant in the form of talc, which consists in the formation of Fe-Cu-Sn and Fe-Cu-Zn solid solutions on the basis of iron and copper, has been revealed. The composition and formation regularities of the transition zones have been revealed. In the transition zones, along with Fe-Cu-Sn and Fe-Cu-Zn solid solutions, areas of a large amount of solid elements are found, which indicates the thermal stability of talc in the firing range of 850-1000 °C.

It was shown that the presence of talc improves the uniformity of the distribution of components in the charge: talc adsorbs on the surface of iron particles and stops the dissolution of graphite in them during the firing process, improves its porous structure, the oil absorption capacity of the fired material and, of course, its tribotechnical characteristics.

Theoretical and practical significance of the study. The effective modes of pressing and firing processes of fired materials of the “iron-bronze” and “iron-bronze” composition types were determined, and a relationship was established between their composition and operational characteristics.

Cold pressing modes of “iron-bronze” and “iron-bronze” compositional charge were developed without the use of technological lubricant. The developed technological variant allows protecting the press plates, and in the latter case, the fired products, from the negative effects of technological lubricant.

The created "iron-bronze" and "iron-bronze" compositional sintered materials have been successfully tested in sliding bearings and other friction units. Their friction coefficient in oil conditions is in the range of *f*= 0,02-0,04, which is equal to the friction coefficient of "bronze-graphite" materials.

Approval and application. The main provisions of the dissertation work were discussed and approved at the following conferences and seminars:

International scientific-technical and scientific-practical conferences:

1.International scientific-technical conference "Intelligent technologies in mechanical engineering", AzTU, 2016.

2. 2nd International scientific-technical conference of doctoral students and young researchers on the topic "Problems of metallurgy and materials science", Baku, AzTU, 2017.

3. "Machines, aggregates and processes. Design, creation and modernization», Conference, Saint Petersburg, 2020.

Republican scientific and technical conferences:

4. 51st scientific and technical conference of professors and teaching staff and postgraduates, Baku, AzTU, 2004.

5. XIX Republican conference of doctoral students and young researchers, ASEU, Baku, 2015.

6. XX Republican conference of doctoral students and young researchers dedicated to the “Year of Multiculturalism” in Azerbaijan, ASOIU, Baku, 2016.

7. Republican scientific and technical conference of students and young researchers on the topic “Youth and scientific innovations” dedicated to the 94th anniversary of the birth of the National Leader of the Azerbaijani people Heydar Aliyev, Baku, AzTU, May 3-5, 2017.

8. Scientific seminar of the department of “Metallurgy and materials technology”, Baku, AzTU, 2018-2023.

Publication of the work. The main content of the dissertation work was published in 22 articles and conference proceedings.

The volume of the dissertation's structural sections and the total volume of the dissertation in characters:

The structure of the dissertation includes the title page (602 characters), table of contents (3,174 characters), introduction (12,220 characters), Chapter I – (31,957 characters), Chapter II – (28,837 characters), Chapter III – (38,355 characters), Chapter IV – (20,407 characters), Chapter V – (23,681 characters), conclusion (5,909 characters), a list of references, and appendices.

The total volume of the dissertation, excluding figures, tables, graphs, appendices, and the reference list, comprises 156 computer-typed pages, including 21 figures, 28 graphs, and 22 tables, and a reference list consisting of 128 sources, amounting to 165,142 characters in total.

MAIN CONTENT OF THE WORK

The introduction indicates the purpose and objectives of the work, substantiates the relevance, scientific and practical significance of the topic, and the importance of the research. It was noted that the use of iron-bronze type castings in the production of antifriction casting parts is more promising. Therefore, the study of such materials is an urgent scientific and technical issue.

In Chapter 1, the analysis of literature data showed that each component included in the material has a specific structure and properties and contributes to the formation of the composition as a whole. However, depending on the type and amount of the included components, as well as the size of the particles, the ratio of their dispersion, synthesis technology, etc., the structure and properties of the composite material can be changed in a wide range [1] [1]. Therefore, the "construction" of a new material is always associated with conducting a number of studies and identifying previously unknown regularities.

Existing casting materials containing anomalous high amounts of copper and its alloys, cast iron waste, glass, solid lubricants and obtained by one-time pressing and baking have low strength and wear resistance in dry friction conditions due to their high porosity [2][2] .

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[1] Особенности структурообразования железобронзы. Мусурзаева Б.Б.

[2] Dəmirtuncqrafit ovuntu materiallarının kimyəvi tərkib və xassələrinə bişirmə temperaturunun təsiri. Musurzayeva B.B., Əbdüləzimova Y.Ə

It has been established that it is impossible to obtain products with low porosity and high strength close to the hardness of compact products using known techniques of one-time pressing. Solving this problem using methods of double pressing-baking, hot pressing and stamping, as well as impregnation of products with easily melting metals is associated with a number of problems and entails an increase in the labor intensity of product preparation.

Scientifically substantiated technological processes for obtaining high-density cast iron products by one-time pressing and baking based on materials containing anomalous high amounts of copper and its alloys, cast iron waste, glass and solid lubricants have not been developed to date [3][3].

The role of technological lubricant in compacting the cast iron charge has not been studied, the formation of the structure and properties of heterogeneously structured high-density cast iron materials, as well as the effect of its content in the charge, have not been considered.

The effect of the shape of metal cast iron and solid lubricants and the size of particles on the structure, physicomechanical and antifriction properties of heterogeneously structured cast iron materials obtained under conditions of effective drainage of gases from the press mold has not been determined.

Based on the above, the need to develop a new direction in the creation of iron-based heterogeneously structured cast iron materials containing anomalous high amounts of copper and its alloys has become apparent [7][4].

The second chapter presents the composition and properties of the constituents of the primary materials, as well as the research methodologies. The following crumb was used for the research: ПЖВ 2.160.26 brand recovered iron (Russian Federation, production of Sulin Metallurgical Plant, ГОСТ 9849-86, gray cast iron, ПМС-1

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[3] Tərkibində bərk sürtkü olan dəmirbürünc ovuntu şixtəsinin preslənməsinin xüsusiyyətləri. Məmmədov A.T., Musurzayeva B.B.

[4] Heterogen strukturlu ovuntu materiallarının yaradılmasının əsas müddəaları. Musurzayeva B.B.

brand copper, ПО - 2 brand tin, Л-63 brand bronze, microtalc, technical sulfur and zinc stearate (TU 6-09-3567-75). Particles of gray cast iron sawdust crushed in a ball mill were used as the crumb.The chemical composition and physical and technological properties of the initial crumb are given in Tables 1 and 2 [4][5].

Table 1

Chemical composition of the initial mixtures

Series No	Name of the grindings	Amount of elements, wt. %, not more than						
		C	Si	Mn	S	P	O_2	Residue insoluble in hydrochloric acid
1	ПЖРВ brand iron casting	0,028	0,12	0,36	0,019	0,12	0,21	0,031
2	Grey cast iron casting	2,1-3,1	2,6-3,7	0,35-0,85	≤0,11	≤0,28	0,48	0,058

Table 2

Physical and technological properties of primary mortars

Series No	Name of mortars	Output of the following particle sizes, mm fraction, %					Spraying-dense, q/sm^3	Flowability, s, not more	Compaction at a pressure of 700 MPa, not less than, q/sm^3
		0,250÷ 0,160	0,160÷ 0,100	0,100÷ 0,071	0,071÷ 0,045	<0,045			
1	ПЖРВ brand iron casting	0÷12	12÷33	18÷38	22÷28	2,4÷3,1	2,6÷2,8	36	7,0
2	Grey cast iron casting	45÷52	22÷28	12÷16	6÷11	0,6	2,5	35	5,6

The batch compositions are given in Tables 3 and 4. The crumb was mixed in a Y-shaped mixer for 1.0 hour. Preliminary studies for cold and warm pressing were carried out in laboratory conditions using manual press molds. The heating temperature of warm pressing It was regulated in the range of 120-150 °C. Prismatic samples with dimensions of 10×10×55 mm and grooves with dimensions of 16×7×11mm mm were pressed in a hydraulic press of the ГП -125 brand. The pressing pressure of the batch was within the limits of

[5] Dəmirtunc ovuntu materiallarının alınmasında pastik təşkiledicilərin rolu. Musurzayeva B.B.

400-1000MPa. The samples were fired in a conveyor-type furnace at 1050-1200 °C.

The density and porosity of the samples were determined by the hydrostatic method. Mechanical properties were determined on the samples and in the details. The hardness was determined in a TK-2M Rockwell device according to ГОСТ 9013-59, and for tensile and bending tests, samples were obtained by hot pressing in a special press mold and subsequent baking according to ГОСТ 1827-72 and tests were carried out according to standard methods.

The microstructures of the samples were studied using microscopes of the «Olympus» (Japan) and «Neofot 021» (AFR), phase analysis was carried out using the DRON-2.0 device, and the chemical composition of the microparticles was determined using the «Camsan» micro-X-ray spectral analyzer. The tribotechnical characteristics of the samples were determined using the СМЦ-2 machine in accordance with ГОСТ 26614-85. The friction coefficient and wear intensity were determined on samples measuring 10×10×16 mm under a pressure of 4 MPa at a shaft rotation frequency of 8 s^{-1} on the СМЦ-2 machine.

In the third chapter, the use of talc together with graphite allows us to realize the principle of pressing a batch without technological lubricants under a pressure of 400 MPa. In this case, the porosity in the press-plates is 10-15 %. Based on this technique, a charge composition was developed to obtain a ferro-bronze containing a solid lubricant. The innovation in the charge is the inclusion of microtalc powder in the composition and changing the proportions of the components. Together, these technological measures lead to an increase in the physical-mechanical and tribotechnical properties of the products [5][6].

Table 3 shows the charge compositions used and the signs of the curves in the graphs.

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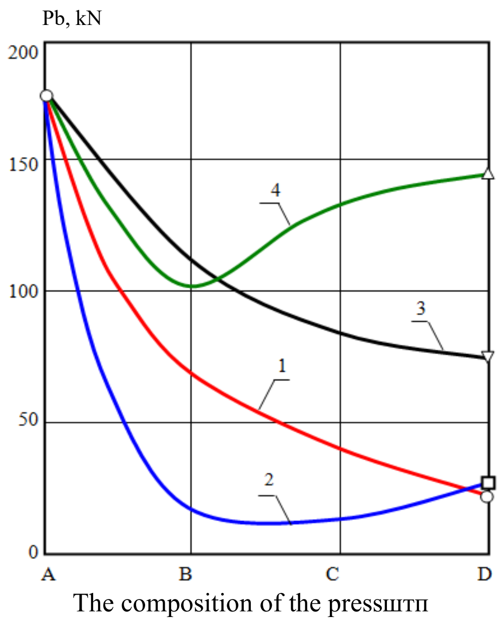
[6] Dəmirtunc ovuntu kompozisiyalarında strukturəmələgətirmənin kinetikası. Məmmədov A.T., Musurzayeva B.B.

Table 3

Ice compositions and signs of curves in graphs

Dew signs / curve number	Amount of flour in the dough, %				
	Cu	Pb	C (graphite)	Talk	Fe
1	5,0	0,3	3,0	4,0	residue
2	7,0	0,5	2,5	3,5	residue
3	20,0	2,5	2,0	2,5	residue
4	45,0	5,0	1,0	1,5	residue

Graph. 1 shows the method of draining gases from the batch during the hot pressing process in a sweating matrix.



Graph. 1. Dependence of the extraction force of press-plates on the chemical composition of the charge: the marking of the curves is given in table 3

Can be seen that as the amount of copper in the charge increases, E decreases slightly (Curve 2). This is explained by the good plasticity and more developed shape of the particles of copper shot compared to iron shot. If the second factor increases the saturation of the charge with gas in a freely dispersed state, then the first factor contributes to the rapid closure of the drainage channels in the body of the freshly molded press-plate during pressing. However, the rate of decrease in E is significantly smaller than when pressing with the use of zinc stearate (Curve 1).

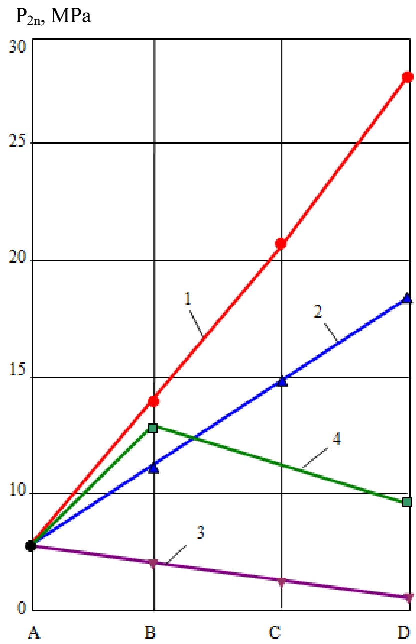
Increasing the amount of tin in the charge even in a small range, i.e. from 0 to 3%, has a positive effect on E (Curve 3). This is primarily due to the poorly developed surface of the sprayed tin powder particles, since powders of such a morphology contribute to the dense packing of the components of the charge and, obviously, to its saturation with gas in the initial state.

The addition of solid lubricants - graphite and talc - to the charge reduces E the more their amount increases. Comparing curves 1 and 4, it can be seen that these lubricants have the same negative effects on drainage (although significantly less), which are characteristic of zinc stearate and any other organic lubricant. Despite all this, using the principle of complex alloying of the iron-based charge with solid lubricants, as well as powders of plastic metals (Cu, Sn), it is possible to achieve a minimum value of the ejection force of the press-mold and sufficient drainage of gases.

The nature of the dependence of the pore pressure of gases in press-castings on the composition of the charge (P_{2n}) is analogous to the nature of the dependence of gas drainage in them (Graph. 2). It should be noted that very small values of P_{2n} are ensured when tin is included in the charge (Curve 3), which is ensured by the shape of the tin particle, as well as its high plasticity. Also, not high values of P2n are ensured in complex alloying. This, as well as low values of the force of removal of press-castings from the matrix, allows us to implement the technological frictionless pressing technique under high pressure (P=1000 MPa) to obtain high-density products from the charge.

The microstructure of the baked iron-bronze containing solid lubricant is multiphase. The compositions of complex phases were studied using X-ray diffraction studies and point chemical analysis.

These are complex solid solutions based on iron (Fe-Cu, Sn-C), as well as copper (Cu-Fe-Sn-C). Moreover, their amount decreases significantly when the firing temperature is increased from 850 to 1150 °C. However, the higher the amount of graphite in the charge and the firing temperatures of the press-slags, the more free cementite is present in the structure.



Graph. 2. Dependence of the pore pressure of gases in the press-slab on the composition of the charge:
the marking of the curves is given in table 3

The strength characteristics of sintered iron bronze with a porosity of 10-15% in the temperature range of 1000-1150 °C are adequate to the strength of cast tin bronze and significantly exceed those of ferrographite with similar porosity. According to its tribotechnical properties, sintered iron bronze can compete with wear-resistant steels in dry friction conditions, and significantly surpass iron and bronze graphites. Its load-bearing capacity in dry friction reaches 10 MPa, and the friction coefficient is 0.046-0.12 in the load range of 2-10 MPa. This is significantly lower than the friction coefficient of iron and bronze graphite, as well as wear-resistant steels.

With the help of a computer, analytical dependences were obtained describing the relationship between the friction coefficient and wear intensity of sintered iron bronze materials with chemical composition, annealing temperature and friction load. The technique of cold pressing without the use of technological lubricants in the charge has been developed and the modes have been optimized. This allows the creation of economically alloyed high-density, strong and wear-resistant alloyed materials containing non-ferrous metals.

In the fourth chapter, an iron-based charge composition containing microtalc and bronze was developed to reduce the cost of the antifriction material. The components in the charge are in the following ratio, wt.%: bronze charge 10-50, microtalc charge 1-5 and the rest iron charge. This charge allows for pressing without technological lubricants, and the baked material obtained from it has a high strength limit in bending [8][7] .

It was found that when the amount of microtalc in the charge increases from 1.0 to 5.0 wt. %, the plastic properties of the material and its ability to resist dynamic shocks deteriorate, while its tribotechnical characteristics, on the contrary, improve (Table 4). The highest mechanical and turbotechnical properties of iron-bronze are achieved at a firing temperature of 1000 °C. A further increase in the firing temperature contributes to the dehydration of talc and a slight densification of the material occurs. In dry friction conditions, the antifriction properties of iron-bronze are higher than those of iron and bronze alloys, as well as several alloyed alloys.

[7] Ovuntu dəmirbürünclərin faza tərkibi və mikrostrukturları. Məmmədov A.T., Musurzayeva B.B.

Table 4

Chemical composition of iron-based charge and characteristics of fired materials

Material brand	Amount of components in the mixture, wt. %		Characteristics of baked materials				
	Bronze powder of the ПЛ-63 brand	Microtalc powder	σ_{te},MPa	σ_{fl},MPa	KC,kc/m^2	f	J
ЖЛ8Т1(A′)	8,1	0,9	251	502	252	0,15	136
ЖЛ10Т(A)	9,9	1,1	256	508	262	0,16	102
ЖЛ3ОТ3(B)	29,9	2,9	158	328	54	0,15	45
ЖЛ50Т5(B)	51	4,9	93	158	36	0,14	125
ЖЛ52Т5(B′)	52,2	4,8	92	138	28	0,14	140

With the help of a computer, analytical dependences were obtained describing the relationship between the friction coefficient and wear intensity of iron-bronze rolling materials and their chemical composition, firing temperature and friction load [6][8].

The chemical composition of iron-bronze fired at a temperature of 1000 °C was studied in microvolumes on a "Comebax" micro-X-ray spectral analyzer in iron and copper radiation (fig. 1 and table 5). For all alloys of iron-bronze, distinct zones of iron and bronze particles are characteristic, and their boundaries, that is, the transition zone, are visible.

The zones of bronze particle location (points 1.4 in sample 15 and points 1.5 in sample 21) are characterized by a large amount of copper and zinc, while the amount of iron varies from 1.103 to 5.6%.

It can be assumed that these zones consist of a complex solid solution of the copper-based Cu-Fe-Zn type.

In the transition zone, the amount of iron increases sharply, but the amount of copper decreases (point 5 in sample 15 and point 3 in sample 21).

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[8] Ovuntu dəmirbürünc materiallarının mexaniki və tribotexniki xarakteristikaları. Musurzayeva B.B.

In the zones where iron predominates, the amount of zinc varies from 0.8 to 1.2%, depending on the location of the point we studied (points 2, 3 in sample 15 and points 2, 4 in sample 21), that is, an Fe-Cu-Zn solid solution is formed on the basis of iron.

It can be assumed that in areas where talc elements are located, there are great opportunities for the formation of ZnO, especially at temperatures above 1000 °C, since in this case the talc structure is decomposed into finely dispersed elements such as SiO_2, $Mg_2Si_2O_6$ and H_2O vapors. Therefore, at point 3 of the 21st standard, a large amount of non-metallic elements (24.13%) and zinc (36.786%) are observed, while the amount of copper and iron is significantly lower.

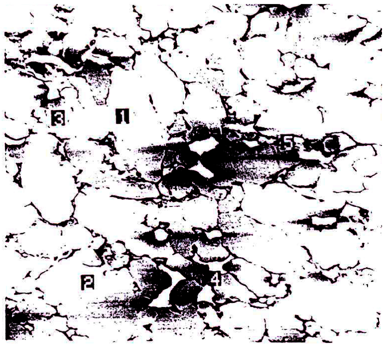
Table 5

Chemical composition of iron bronze in microvolumes

Number and batch composition of the alloys	Acquisition modes	Number of micro analysis points	Amount of components, wt. %			
			Fe	Cu	Zn	Talk
Aluminum 15, bronze-50%, talc-5.0%, iron-casting	P=700 MPa, T=950 °C	1 2 3 4 5	1,1 98,4 98,7 3,6 23,4	80,5 1,1 1,02 74,78 54,16	18,34 0,38 0,23 21,56 22,43	— — — 0,09 0,045
Aluminum 21, bronze-40%, talc-4%, iron-casting	P=700 MPa, T=1050 °C	1 2 3 4 5	5,44 98,77 27,7 98,9 5,6	77,11 0,86 11,35 0,9 78,06	17,46 0,36 36,8 0,5 16,4	— 0,0222 24,128 0,0218 —

If we observe the change in this ratio of copper and zinc, which is initially 4÷1, we can see that at which points a Cu-Zn-Fe solid solution is formed, at those points this ratio varies from 3.47:1 to 4.74:1, but at the points where iron-based Fe-Cu-Zn is formed, it varies from 1.84:1 to 4.2:1. This confirms our hypothesis that during the cooking process either copper-based or iron-based Cu-Zn-Fe solid solutions are formed, the compositions of which are not constant and depend on the cooking temperature and other factors [18][9].

The process of cold pressing of iron-bronze castings in a “sweating” matrix without the use of lubricants has been developed and efficient process modes have been determined. The novelty of the developed casting material is the use of microtalc as a thermally resistant component in its composition for the first time.



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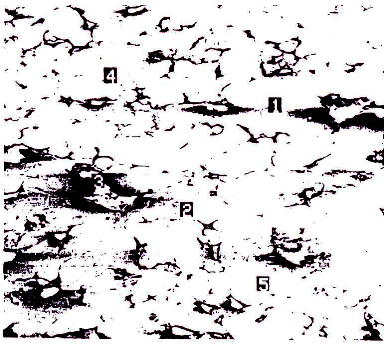

b

Figure 1. Location of points used to determine the chemical composition of the material: ×200; a-setting 15; b-setting 21

[9] Принципы создания порошковой железо-бронзы. Мусурзаева Б.Б.

It has been determined that microtalc is thermally resistant to temperatures up to 1000 °C in the composition of the castings [9][10].

In Chapter 5, the creation of a “cast iron bronze” type composite material was investigated in order to increase the cost of antifriction materials, improve the processability of the charge and improve the properties of the obtained parts. The composition of the charge for obtaining the material consists of the following components, wt.%: interdendritic point graphite cast iron - 54.5-64.5; bronze of the Л 63 brand - 5-20; technical sulfur - 0.25-1.0 and the rest of the iron. The composition of the effective “cast iron bronze” material, which consists of 54.5% cast iron, 10% bronze, 0.5% sulfur and the rest of the iron, was determined and given the conditional brand ЖЧ54.5Л10К0.5 [13][11] . The effect of the baking temperature and duration on the antifriction and mechanical properties of the ЖЧ54.5Л10К0.5 material was determined. It has been found that the highest σ_d, σ_e, KC, HB, f and J are obtained when the material is fired at a temperature of 1200 °C. This effect is explained by improving the interaction of particles of different types, such as cast iron, iron, and liquid bronze, with each other and partial homogenization of the structure [10][12].

An increase in the bending strength limit ($\sigma_ə$) of the parts is achieved only when fired at a temperature of 1200 °C. In this case, the hardness (HB) of the sample tends to decrease. At the same time, decarburization occurs in the material. The use of endothermic gas in firing leads to a slight decrease in carbon in cast iron castings [11][13].

To improve the mechanical properties and workability of the “cast iron bronze” composition under dry friction conditions, the cold pressing technology was applied in the “sweating” matrix. The most efficient firing temperature of the compositions obtained by this

[10] «Tərləyən» matrissada presləməklə alınan ЖЧ54,5Л10К0,5 ovuntu kompozisiyanın xassələri. Musurzayeva B.B.

[11] “Dəmirçuqunbürünc” ovuntu şixtəsiinin səmərəli tərkibinin seçilməsi. Musurzayeva B.B.

[12] ЖЧ54,5Л10К0,5 ovuntu kompozisiyasının struktur və xassələrinə bişirmə rejimlərinin təsiri. Musurzayeva B.B.

[13] Состав, структура и свойства антифрикционной порошковой композиции «железо-чугун-латунь». Мамедов А.Т., Мусурзаева Б.Б.

method was determined to be 1200 °C, and the firing time was 1 hour.

It was determined that as a result of the application of this technology, the physical-mechanical and antifrictional properties of the material increase almost 2 times. This is due to the active drainage of gases from the press mold during pressing, the formation of reliable mechanical and juvenile (bare) contacts of particles of different types during pressing, and as a result, the activated particles actively contribute to the firing process.

The new "iron-cast iron-bronze" alloy composition obtained using cast iron sawdust waste can compete with various brands of bronze in terms of its physical-mechanical and operational properties, especially tribotechnical characteristics [12][14]. In terms of its cost, the "iron-cast iron" type composition is several times cheaper than the cheapest bronze brands. It is precisely due to this factor that the newly developed alloy material, due to its composition and pressing in a "sweating" matrix, has great prospects and can be successfully applied in various fields of industry [19][15].

GENERAL CONCLUSIONS

1. For the first time, the possibility of obtaining "iron-bronze" and "iron-bronze" type baked materials with an anomalous high content of copper, tin, bronze inclusions, graphite and talc in the composition of the alternative and solid lubricants of bronze, bronze-graphite and ferrographite has been shown [20][16]. The kinetics of structural processing of these materials, the dependences between the parameters of cold pressing and baking technologies have been determined. The use of anomalous high content of plastic inclusions (copper, tin and bronze) and solid lubricants in the batch allows cold pressing of the batch without the use of technological lubricants. As

[14] Dəmirçuqunbürünc antifriksion ovuntu kompozisiyasının xassələri. Musurzayeva B.B.
[15] «Dəmirçuqun» tip ovutu kompozitlərinin elastiki-plastiki deformsiyasının xüsusiyyətləri. Məmmədov A.T., Hüseynov M.Ç., Musurzayeva B.B. Cəfərova A.A.
[16] Microstructure and elemental analysis of iron-based powder composite materials. Musurzaeva B.B.

a result, higher physical-mechanical and tribotechnical properties of the material are obtained [14][17].

2. To obtain a compositional alloy material, a charge containing copper (9-27 %), tin (0.5-3.0 %), the rest iron alloys, as well as solid lubricants - graphite (1.5-2.5 %) and talc (2.0-3.5 %) was processed [17][18]. This composition ensures uniform distribution of components in the charge, and the products obtained from the charge have a sufficiently high oil absorption capacity and surface cleanliness [16][19].

3. The reasons for the change in the physical and mechanical properties of the "iron-bronze" type material depending on the pressing and firing modes have been determined. These are related to the densification of technologically unlubricated iron-bronze during pressing and the structuring properties during firing, and are accompanied by the formation of a liquid phase during firing [18][20].

4. It was determined that in the "iron-bronze" composition, cementite elements are mainly formed around the pores and in the vicinity of excess copper and bronze elements, with a predominance between them. On this basis, a hypothesis is put forward that the local cooling rate in the areas where excess copper and bronze elements are located determines the formation of cementite elements.

5. It was shown that, regardless of the amount of copper and tin, high strength of the samples is achieved in the temperature range of 1000-1150 °C. At a porosity of about 16-17%, these samples are adequate to cast tin bronze in terms of strength characteristics and significantly exceed those properties of ferrographite with similar porosity. This effect is associated with an improvement in the quality of adhesion of particles of different types under technological lubrication-free pressing conditions. The fact that it has a sufficiently

[17] Evtektik kompozisiya materiallarında komponentlərin qarşılıqlı təsir məsələləri. Mehdiyev R.K., Musurzayeva B.B., Rüstəmova S.M.

[18] Dəmirtuncqrafit ovuntu materiallarının alınmasında bişirmə temperaturunun rolu Musurzayeva B.B.

[19] Пропитка порошкового композита жидким металлом в процессе литья. Расулов Ф.Р., Мусурзаева Б.Б.

[20] Принципы создания порошковой железо-бронзы.Мусурзаева Б.Б.

high strength after annealing determines the increased load-bearing capacity of ferrobronze compared to bronze, bronze-graphite and ferrographite. The load-bearing capacity of ferrobronze is 2÷12MPa, and the friction coefficient is in the range of 0.046-0.12.

6. A batch was processed to obtain a baked “iron bronze”. The composition of the batch consists of bronze (10-50%), talc (1÷2%) and the rest of the iron flakes. In this case, the size of the talc flakes is 10-25 µm, and the ratio of the size of the particles of bronze and talc flakes is within 2:1÷10:1. This ratio allows to significantly increase the strength of the baked material in static bending, the reason for which is associated with the fact that the bronze plates evenly distributed in the iron matrix slow down the dispersion [15][21].

7. The effect of the firing temperature of the press-molds in the range of 800-1050 °C on the physical and mechanical properties of "iron-bronze" was determined. It was shown that the highest strength of the material is achieved at a firing temperature of 1000 °C. With a further increase in the firing temperature, the strength characteristics of the material decrease due to dehydration of talc and collapse of its structure, which leads to a weakening of the bond between particles.

8. It was found that increasing the amount of talc in the studied materials worsens their plasticity properties. In conditions of friction with oil, iron-bronzes have high tribotechnical characteristics. In this case, their load-bearing capacity is 8 MPa, but in dry friction conditions they wear out quickly due to the lack of stable solid elements in their structure.

9. “Iron bronzes” can be recommended for the production of friction pads for small and medium-sized electric motors, and “iron bronzes” for operation in more severe conditions. However, the relatively high cost of this material for mass demand dictated the development of cheaper substitutes. Approaching the issue from this context reveals the problem of using cheaper substitutes. The use of sawdust waste from cast iron, which is considered a good antifriction material, appears as a more relevant issue. Therefore, in the next

[21]Dəmir-bürünc ovuntu kompozisiyalarının yaradılma imkanlarının araşdırılması. Hüseynov R.Q., Musurzayeva B.B

stage of research, a new antifriction material of the “iron bronze” type was developed [22][22].

10. The composition of the batch of the new antifriction material of the cast-iron-bronze type is 54.5-64.5% cast-iron slag, 5-20% Л63-brand bronze slag, 0.25-1.0% technical sulfur and the rest is iron slag. As a result of the research, the most effective composition was selected as ЖЧ54.5Л10К0.5 brand “cast-iron-bronze” and this material was subjected to detailed research. By applying the pressing technology in the “sweating” matrix and baking at a temperature of 1200 °C, a composite material with high physical-mechanical and antifriction properties was synthesized. This material is capable of competing with antifriction materials such as bronze, bronze-graphite, and ferrographite.

The main content of the dissertation is published in the following works:

1.Мусурзаева Б.Б. Особенности структурообразования железобронзы. “Doktorantların və gənc tədqiqançıların XIX respublika elmi konfransının materialları”. Aspirant və gənc tədqiqatçıların elmi-texniki konf. materialları. Bakı, AzTU, II hissə, 2004, s.164-165.

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