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Properties of powdered metal-ceramic materials obtained from by-products of the mining and metallurgical industry of Uzbekistan

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Abstract. One of the actual problems of production is the use of various waste products, in particular metallurgical. The method of powder metallurgy allows the use of waste from metallurgical industries. This is used in this work to obtain an antifriction porous material based on iron and copper. Iron and copper powders obtained at the Almalyk Mining and Metallurgical Combine by restoring iron and copper scale of metallurgical plants are used. Pyrite, a waste product of the Almalyk Mining and Metallurgical Combine, is used as an additive material. Tests have shown the possibility of manufacturing metal-ceramic iron and copper-containing antifriction alloys with pyrite additive based on local raw materials.

1 Introduction

The main requirement for structures for various purposes is their maximum use with minimal production costs. One of the conditions for achieving maximum efficiency is to reduce material consumption while using modern technologies for manufacturing parts. In structures, friction units most often fail, which leads to additional costs for spare parts and losses of technological time. In this regard, antifriction parts obtained by powder metallurgy are widely used in mechanical engineering [1-5]. This method allows you to obtain parts with specified dimensions, physical and mechanical properties, and chemical composition. At the same time, the material utilization factor is 0.95-0.98 [3].

Firms producing reconstituted iron powders use either pure ore concentrate or pure rolling scale as raw materials. The companies «Heganes Corporation», as well as Japanese and Chinese companies producing iron and copper powders, use the rolling scale as raw materials. The main consumer of powder products is the automotive industry. The mass of powder parts in cars is constantly growing at about 12 - 15 kg per European car. In our case, the objects were products obtained by pressing and sintering powders from local raw materials.

Iron powders were obtained at the Almalyk Mining and Metallurgical Combine by restoring the iron scale of the Bekabad Metallurgical Plant, and copper powders were obtained from the copper scale of the Almalyk Mining and Metallurgical Combine. The restoration was carried out in the medium of drained hydrogen at a temperature of 1100-

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1150 ^{0}C, the copper scale at 900 ^{0}C. Pyrite, which is a waste of Almalyk mining and metallurgical production, was used as a sulfur-containing additive in iron scale.

2 Methods

Graphite and pyrite were used to make a charge based on iron powder. Graphite was taken elemental or pencil according to GOST 4404-78 "Graphite for the production of pencil rods Technical conditions". Pyrite was used after grinding to a fraction of 0.45-0.16 mm. Powder mixing and charge preparation were carried out in cone mixers with the addition of gasoline and zinc stearate. The graphite content was constant - 2%. The pyrite content was: 0.5; 1.0; 1.5; 2.5; 3.0; 3.5; 4.0 %. Aluminum powder was added to the charge based on copper powder to obtain aluminum bronze. Aluminum powder was obtained from aluminum chips by grinding. Pyrite was added from 1 to 4%. After the preparation of the charge, the necessary samples were pressed following the required dimensions and configuration for tensile and compression tests.

The tests were carried out according to GOST 25698-83 "Powder products. Methods for determining hardness" GOST 18227-Powder materials. The method of tensile testing. Samples in the form of bushings were subjected to radial compression tests according to GOST 26529-85 – "Powder materials. Radial compression test method". Following this GOST, the tensile strength under radial compression was determined:

$$\sigma_{rc} = P_{max} \cdot (D - a) / L \cdot a^2$$

where, P_{max} – maximum destructive load;
D - outer diameter of the sleeve;
a – sleeve wall thickness;
L – length of the cylindrical part of the sleeve.

Pressed iron-based samples were sintered at a pressure of 600 MPa. To do this, the pressings were packed in stainless steel containers, after which they were covered with an asbestos sheet. Cast iron shavings with a thickness of about 40 mm were poured onto the asbestos sheet, the container was closed with a lid, and the cracks were smeared with refractory clay. Sintering of iron-based samples was carried out at a temperature of 1100 ^{0}C for 2 hours. After sintering, the containers were cooled in the air. Sintering of copper-based samples was carried out at a temperature of 850 ^{0}C. The obtained samples were subjected to hardness and strength tests by the above standards. Density and porosity were determined by GOST 18398-73 - "Powder metallurgy. Methods for determining density and strength". The oil content in impregnated powder products was determined by the weight method according to GOST 24903-81.

3 Research results

Tests of samples of ferro-graphite alloys obtained based on iron powder from a reduced metallurgical scale showed (Fig.1) that when pyrite is introduced into the charge from 0.5 to 1.5% leads to a certain decrease in density and an increase in oil absorption. At the same time, there is a decrease in hardness and strength. However, with a pyrite content of up to 1%, all properties meet the requirements for iron-based antifriction materials.

It should be noted that the microstructure of the alloy is a ferrite-perlite base, in which areas of graphite and sulfide inclusions are visible. With a charge content of more than 2% pyrite, porosity increases sharply, which should be associated with the gas formation during the decomposition of FS_2 during sintering. An increase in porosity leads to a decrease in density and an increase in oil absorbency. Strength properties and hardness are sharply reduced.

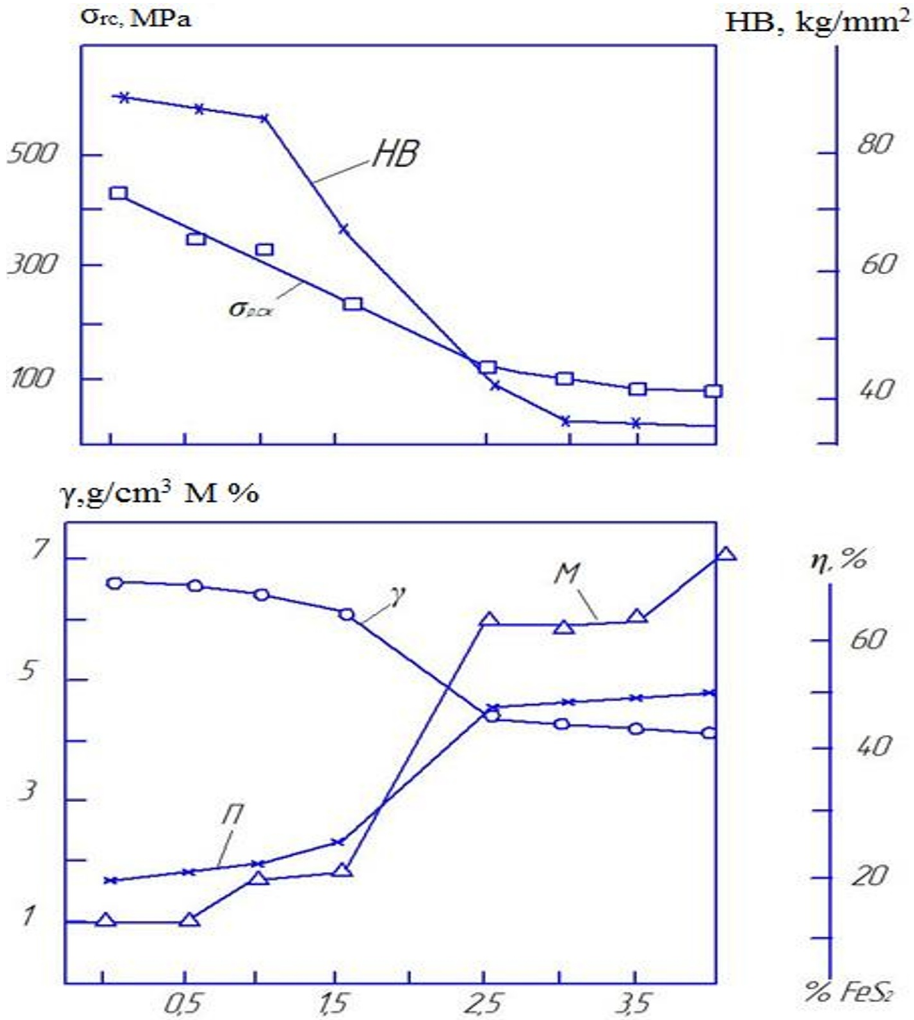

Fig. 1. Dependence of hardness HB, radial compressive strength σ_{rc}, density γ, porosity P, oil absorption M of a porous antifriction alloy based on iron on the content of pyrite in the charge

Separately, samples were made for conducting studies of mechanical characteristics based on copper with a content of 5 to 20% Al, where 1 to 4% was used as a sulfur-containing additive. Initial experiments were carried out on samples without pyrite at different percentages of aluminum to establish the nature of changes in the mechanical properties of aluminum powder bronze. The influence of the sintering temperature on the hardness and strength of the alloys was determined (Fig.2,3), at a pressing pressure of 500 MPa.

Analyzing the results obtained, it can be noted that the hardness and strength of the obtained samples increase with an increase in the percentage of aluminum and with an increase in the sintering temperature. The most advantageous sintering modes are sintering temperatures from 800 to 900 ^{0}C with aluminum content of 20%.

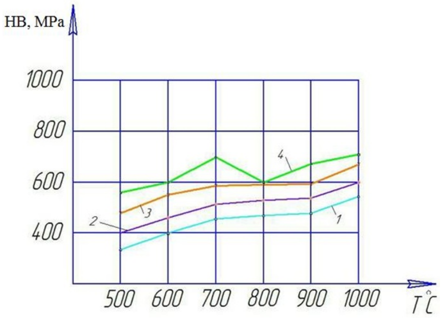

Fig. 2. Changes in the hardness of aluminum bronze samples depending on the sintering temperature; 1 - 5% Al, 2 - 10% Al, 3 - 15% Al, 4 - 20% Al.

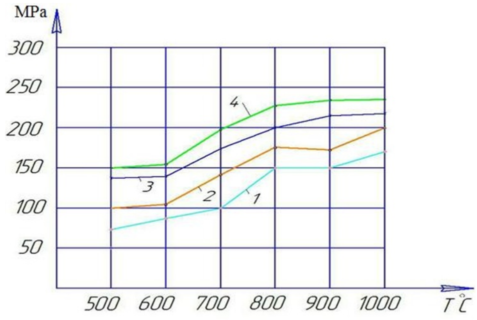

Fig. 3. Changes in the strength of aluminum bronze samples depending on the sintering temperature; 1 - 5% Al, 2 - 10% Al, 3 - 15% Al, 4 - 20% Al.

For materials intended for friction units, the main requirement is the ability to resist the processes of setting and jamming.

The introduction of substances capable of playing the role of dry lubricants into the composition of porous bearing materials makes it possible to resist the processes of setting and jamming. One of such materials is sulfides. In particular, during the production of copper, waste from metallurgical production is formed - pyrite (FeS_2). To determine the effect of pyrite content on mechanical properties, tests were carried out on the hardness and strength of aluminum bronze with an aluminum content of 20% and pyrite additives from 1 to 4% (Fig.4,5).

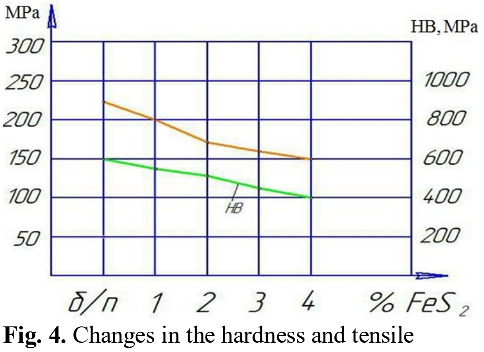

Fig. 4. Changes in the hardness and tensile strength of aluminum bronze depend on the pyrite content. Sintering temperature 850 ^{0}C

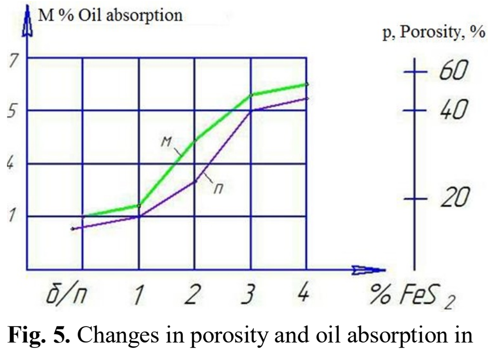

Fig. 5. Changes in porosity and oil absorption in aluminum bronze depending on the pyrite content

As can be seen from the graphs, the highest values of hardness and strength in aluminum bronze are achieved with a minimum content of pyrite. However, for materials intended for sliding bearings, the porosity of the material and its oil absorption is of great importance. From this point of view, the optimal pyrite content is 1.0-1.5%.

4 Discussions

One of the most pressing problems of modern materials science is the development of bearing materials for operation in severe friction conditions. Such conditions are the operation of friction pairs with a limited supply of lubricant, with minor loads (up to 1 kg/cm^2) and small (less than 0.1 m/sec) sliding speeds; at elevated loads (more than 100 kg/cm^2), elevated and high sliding speeds (above 4-10 m/sec); elevated and lowered temperatures [6-10]. Under these conditions, lubrication is not effective and the surfaces of the rubbing bodies come into contact.

To ensure the necessary antifriction properties when creating bearing materials, they are guided by the basic principle: heterogeneity of their structure in this regard, Sharpie has been widely instilled, which consists in the fact that bearing alloys consist of solid-phase inclusions distributed in a plastic metal base.

Such a structure is observed in all cast alloys: bronzes, babbits, brasses, recognized as the best bearing materials. They meet the basic conditions that antifriction materials must meet: a) the pressure is transferred to solid particles that are not able to lift the shaft neck; б) the plasticity of the binding matrix, which allows the working surface of the bearing to deform and take shape closest to the working profile of the shaft, this reduces the possibility of local pressure peaks, which are a smooth cause of bearing failures.

The main drawback of these materials is their inability to work in the absence of lubrication.

The powder metallurgy method makes it possible to develop simple bearing materials based on copper and iron, which have comparable properties and significantly higher wear resistance compared to cast alloys. This has determined the widespread use of metal-ceramic antifriction materials in the place of cast-bearing alloys in various friction nodes.

The improvement of the friction characteristics of such materials is determined by the presence of pores filled with oil and ensuring the manifestation of the effect of self-lubricity at the time of termination of the supply of lubricant from the outside during the operation of the bearing.

The implementation of the self-lubricity effect, due to the release of oil from the pores and the formation of the thinnest films on the friction surface, is the basic principle of creating porous antifriction materials that ensure long-term and reliable operation of the bearing assembly.

Regulation of the composition, structure, size, and number of pores allows the direction to change the frictional characteristics of friction units.

The results of experiments on the manufacture of metal-ceramic antifriction materials based on iron and copper powders obtained from by-products of the mining and metallurgical industry of Uzbekistan show the possibility of using these materials as sliding bearings.

5 Conclusions

Based on the conducted research, the following conclusions can be drawn:

1. The prospects of using by-products of the mining and metallurgical industry of Uzbekistan as antifriction materials are shown.
2. Sintered antifriction metal-ceramic alloys based on iron and copper powders meet the requirements of technical specifications for such materials in terms of mechanical properties.
3. It has been established that pyrite with a content of 1 to 1.5% in metal-ceramic alloys based on both iron and copper can be used as an antifriction additive.

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