The properties of the powder that makes the basis of hard alloys used in the crushing of underground resources

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Abstract. Today, many countries are extraction the underground resources (non-ferrous and rare metals) by having a leading processing plants. In Uzbekistan, metals such as gold, silver, copper, uranium, rhenium, and tungsten are mined from underground resources and produced as finished products. A significant part of the costs of the extraction of underground resources is spent on the processes of crushing and grinding crushing minerals. Hard alloys used in the process of crushing and grinding ores are produced based on metals such as tungsten and cobalt. This article presents scientific-practical research on the properties of powders that form the basis of tungsten carbide-cobalt-based hard alloys used in crushing underground resources. During the research, the chemical composition of tungsten and cobalt carbide powders chosen as raw materials, the location of the powders in the raw materials, the granulometric sizes of the powders, and their morphology were studied. In all conducted studies, tungsten carbide powders produced at the JSC “Almalyk MMC” were used as a raw material to prepare samples of tungsten carbide-cobalt-based hard alloys and also as a binder. Cobalt powder produced in this enterprise was selected. All studies were carried out on a scanning electron microscope, JSM-IT200 (JEOL, Japan), at the Uzbekistan-Japan Youth Innovation Center.

1 Introduction

Various technical methods and equipment are utilized in the mining and metallurgical sectors worldwide to prepare materials for processing. Thus, one of the most pressing problems of the day is the advancement of technical plans and apparatus. Many nations throughout the world, including the developed United States of America, Germany, China, Japan, Russia, Austria, and others, are conducting a great deal of study in this area. This means that the need for high-quality parts made of hard alloys based on cobalt and tungsten carbide, which resist corrosion and are frequently used in the production of products heated

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and cooked using the powder metallurgy method, calls for the development of a technology that will allow for the production of high-quality, corrosion-resistant heated and cooked hard alloy products using an efficient process that guarantees the implementation of resource conservation. is crucial. In the development of corrosion-resistant hard alloys, the quality of the raw materials that form the basis of the hard alloy is of great importance[1].

2 Methods

Today, there are standard methods of powder analysis, such as determination of powder dispersion [1], determination of oxygen content [2], determination of particle density [3-5], and determination of the granulometric composition of powders by the X-ray sedimentation method [6-8], but these methods are used to determine the quality of hard alloys made from powder. does not provide complete information on the correct (mechanical and operational) properties. Therefore, it is necessary to use additional techniques, such as electron microscopy and X-ray phase analysis, for scientific and practical research of the properties of powders used in the casting of hard alloys.

The electron microscopic method requires a lot of work in large-scale production, but the electron microscopy method allows studying the surface morphology of the primary powder components (tungsten carbide, cobalt) based on a tungsten carbide-cobalt hard alloy. In addition, this method makes it possible to evaluate the properties of tungsten powders and large fractions of carbides from them. By analyzing the properties of powders, it is possible to scientifically and practically analyze the influence of hard alloys on their properties, such as hardness, bending strength limit, brittleness, and resistance to abrasive wear.

3 Results and Discussion

Physicochemical properties and morphology of cobalt powders. Cobalt powder is an important binding component for obtaining hard alloys belonging to the VK group. Cobalt powder in a hard alloy serves as a binder between tungsten carbide particles. Depending on the content of cobalt and its properties of distribution in the hard alloys, the physical-mechanical and operational properties of the final alloyed products change. The quality of the mixture prepared for pressing tungsten carbide products depends on the correct choice of cobalt powder. Therefore, it is an important task to study the properties of cobalt powders in powder metallurgy. There are standard methods for testing cobalt powder, such as determining the average size of particles, determining the composition of particles, and determining the amount of oxygen in the mixture. These methods are not always sufficient to fully evaluate the quality of cobalt powder. Therefore, it is appropriate to use methods such as electron microscopy, FTIR and X-ray phase analysis. Cobalt powder PK-1u, which meets the requirements of the literature [9,10], was used for the hard alloy's binding component. Table 1 displays the granulometric and chemical makeup of cobalt powder.

<table>
<thead>
<tr>
<th>Co, at least, %</th>
<th>Amount of additives in the composition, % max.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fe</td>
</tr>
<tr>
<td>99.25</td>
<td>0.2</td>
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</tbody>
</table>

Table 1. Chemical composition of PK-1u brand cobalt powder.
Fig. 1. Chemical composition of cobalt powder.

Figure 2 shows a picture of the electron microscope taken with iron, silicon, nickel, and copper elements turned off while determining the chemical composition of cobalt powders. Marked in the picture is the image of the carbon content of the clay in the sample placement part of the carbon electron microscope.

The granulometric size of the selected cobalt powder is as follows: \( \leq 1 \, \mu m \) - 3.7 percent, 1-10 \( \mu m \) - 66.3 percent, 10-15 \( \mu m \) - 19.7 percent, 15\( \leq \mu m \) - 10.3 percent (see Fig. 3).
X-ray phase analysis showed that the analyzed cobalt powders are free of impurities. Cobalt was found to have two crystal modifications: \( \alpha \)-Co (hexagonal) and \( \beta \)-Co (cubic). In pictures 4 a, b, and c, the shape of cobalt looks like a circle, but when magnified \( x7,000 \) and \( x8,000 \) times, it was found that their shapes are hexagonal and cubic.

Based on the scientific and practical research conducted, it was determined that the cubic modification of cobalt is preferable to the practice of the technology of sintering hard alloys. The mechanical and operational properties of hard alloys sintered from cubically...
modified cobalt powders sintered in the same conditions, environment, and technological regimes show results that are 5–10% higher than those of hard alloys sintered from hexagonally modified cobalt powders.

Chemical composition and morphology of tungsten carbide powders. The analysis of tungsten carbide particles, which form the basis of hard tungsten alloys, is the main criterion that determines the properties of the final product. Incomplete carburization of tungsten carbide powders or technological defects in the process leads to the formation of W2C non-stoichiometric tungsten semi-carbide in addition to tungsten monocarbide, and this means that uncarbided tungsten is in free form in the powder. The use of such powders in the production of hard alloys hurts the quality of the final product, and such carbides are not used in the production.

Sometimes, when studying the morphology of the tungsten carbide structure, the presence of fine and very fine powders, as well as large agglomerates, can be determined [7-9]. For the presence of agglomerates in the carbide not to affect the final properties of the products, an additional process can be introduced into the technological scheme; that is, during the processing, they can be easily crushed to their original size as a result of intensive mixing and grinding.

The incomplete carbidization process of tungsten particles with sizes larger than 20 μm, causes the appearance of free carbon in the hard alloy. The presence of free carbon leads to the deterioration of the quality of the hard alloy [8,10]. The chemical makeup of the tungsten carbide powder produced at the SPA following GOST 3882 and TU-48-19-60-78 specifications for the manufacturing of hard alloys and rare metals at Almalyk MMC JSC is displayed in Table 2.

Table 2. Chemical composition of tungsten carbide powder.

<table>
<thead>
<tr>
<th>W, %</th>
<th>C generalized, %</th>
<th>Amount of additives in the composition, % max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>93.871</td>
<td>6.006</td>
<td>C free 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S 0.023</td>
</tr>
</tbody>
</table>

![Fig. 5. Chemical composition of tungsten carbide powders.](Map_002_wholespectrum)
Fig. 6. Arrangement of tungsten carbide powders in the mixture.

Figure 6 shows an electron microscope photo taken with sulfur turned off while determining the chemical composition of tungsten carbide powders.

The granulometric size of the selected tungsten carbide powder is as follows: ≤8 μm – 1.6 percent, 8-10 μm – 4.9 percent, 10-12 μm – 13.1 percent, 12-20 μm 80.04 percent, 20≤ μm – 0.36 percent (Figure 7).

Fig. 7. Surface morphology of tungsten carbide powders.

At first, when the powders were magnified x1500 times, tungsten carbide grains with a size of 30–50 μm appeared to be numerous (Figure 7 a), but at x5000 and x10000 magnifications, several tens of particles were found to be agglomerated. (see pictures 7 b, c, and d).
X-ray phase analysis of tungsten carbide powders showed the presence of hexagonal powders in all studied samples. This structure is used in practice for the production of hard alloys. No foreign matter was found [11-14].

4 Conclusions

As a result of the conducted scientific-practical research, the results of the study of the morphology of cobalt powders show that the surface of the cobalt particles used in "SPA to produce hard alloys and rare metals" has a good flat morphology. Very large particles and agglomerates are not found, and Hard alloys based on cobalt and tungsten carbide can be produced. Analyzing all the studied tungsten carbide powders, we can conclude that the shape and size of the carbide particles mainly depend on the particle size of the raw material. Therefore, the selection of granular tungsten powders is a very important and fundamental task in the technology of hard alloy sintering. It is not appropriate to choose a wide range of particle size distributions in raw materials. The presence of both a small fraction and an excessively large fraction leads to the appearance of unevenness in the structure of sintered tungsten carbide products, which, in turn, leads to changes in physical and mechanical properties. In addition, the presence of tungsten powder larger than 20 microns leads to poor carbidization, resulting in the formation of free carbon and free tungsten.

References

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