Hardness of products from electroerosive cobalt-chrome powders, obtained by additive technologies

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Abstract. The wide use of the EED method for processing metal waste into powders for the purpose of their reuse and application in additive technologies is hampered by the lack in the scientific and technical literature of full-fledged information on the effect of the initial composition, regimes and media on the properties of powders and technologies of practical application. Therefore, in order to develop technologies for the reuse of electroerosive powders and to evaluate the effectiveness of their use, complex theoretical and experimental studies are required. The purpose of the study is to investigate the hardness of additive products from electroerosive cobalt-chrome powders. Tests on the hardness of the samples on the surface and cross-section were carried out using an automated micro-hardness analysis system DM-8 using the micro-Vickers method with an indenter load of 200 grams per ten prints with a free choice of the site of injection. Based on the results of the conducted studies, it has been experimentally established that the microhardness of additive products obtained from electroerosive powders with an average particle size of 52.5 μm is 5.7 Gpa.

1. Introduction
Additive technologies (AT) for the production of products from materials based on metals and alloys are one of the most promising and actively developing areas of production [1-10]. Proceeding from the peculiarities of the methods for obtaining spherical powders with the aim of obtaining spherical granules of regulated granularity, the electroerosive dispersion technology is proposed, which is characterized by relatively low energy costs and ecological purity of the process[11-12].

The wide use of the EED method for processing metal waste into powders for the purpose of their reuse and application in additive technologies is hampered by the lack in the scientific and technical literature of full-fledged information on the effect of the initial composition, regimes and media on the properties of powders and technologies of practical application. Therefore, in order to develop technologies for the reuse of electroerosive powders and to evaluate the effectiveness of their use, complex theoretical and experimental studies are required.

The purpose of the study is to investigate the hardness of additive products from electroerosive cobalt-chrome powders.

2. Materials and methods
For the implementation of the planned studies, wastes of the cobaltochrome alloy of the brand KHMS "CELLIT" were chosen. As a working fluid, butyl alcohol (butanol-1) was used. For the production of cobalt-chrome powders, a unit for EED of conductive materials was used. Dispersion parameters: voltage 100 V, capacity 48 μF, repetition rate 120 Hz.

The phase composition of the samples was studied by X-ray diffraction on a Rigaku Ultima IV diffractometer in Cu-Kα radiation (wavelength λ = 0.154178 nm) using Soller slits. The diffraction spectrum for the phase analysis is sampled according to the θ-2θ scanning scheme with Breguot-Brentano focusing in the angular interval 5 ... 100 deg. 2Θ. The shooting is carried out in point-by-point mode with scanning step Δ(2θ) = 0.02 deg, speed 0.6 deg / min, working voltage 45 kV, current 200 mA. To refine the profile of the experimental radiographs, the software package PDXL RIGAKU was used.

Subtraction of the background was carried out by the Sonneveld-Visser method, the smoothing of the experimental profile by the Savitsky-Naked method, and the separation of the components kα1 and kα2 by the Racinger method. To describe the diffraction maxima, a superposition of the Gaussian function and the Lorentz function was used. The approximation of each of the reflections in the diffractograms of the samples studied by the pseudo-Voigt function made it possible to accurately determine the position of the reflections, taking into account the displacement caused by the overlap of the reflexes, at half the intensity maximum (FWHM) and intensity. The phase composition of the coatings was determined using an ICCD PDF-2 database (2014).

Dispersing in a liquid with ultrasound. Research Methodology (FR 1.27.2009.06762 "Method for measuring particle size in suspensions, emulsions and aerosols in the nanometer and colloidal ranges using the dynamic light scattering effect"). Sample preparation: dispersion of the sample in a liquid. Background measurement - in order to reduce the influence of the measuring liquid, a background measurement is carried out before each measurement. Any contamination from previous measurements is measured and its effect on the current result is eliminated. Measurement of the particle size distribution: a sample with a volume of about 1-5 g was placed in a liquid dispersion module (500 ml volume). The measurement was started automatically, as soon as the absorption value reached the specified value. Measurement parameters: Measurement type - Fraunhofer method; the measurement range is 0.1 [μm] — 1021.87 [μm]; resolution - 102 channels (20/383 mm); the duration of the measurement is 100 (scans); regularization is an average model.

3. Results and discussion
   The results of particle size measurement are shown in Figure 1.
Figure 1. Size distribution of microparticles of "CoCr" powder

Integral curve and histogram: integral curve in coordinates $Q_3 (x) = f (\mu m)$ (left scale) - each point on the curve, how much% of the sample has a particle size less than or equal to a given one. Histogram in the coordinates $q_3 (\times) = f (\mu m)$ (right scale) is the amount of a sample with a given particle size.

It was found that the average particle size is 52.5 $\mu m$, the arithmetic value is 52.496 $\mu m$.

Information diffraction patterns can be used not only to determine the particle size, but also to analyze their shape. Particles of a nonspherical shape scatter radiation in their preferred spatial directions. If a small number of particles do not enter the laser beam, an analysis of their shape can be performed on the basis of the information obtained. Due to the unique possibility of moving in a converging laser beam, in analyzing the shape of the particles, the measuring cell is brought closer to the detector, so that the first diffraction maximum of radiation scattered by the medium-sized particles enters the detector regions sensitive to the shape of the particles. Since the diameter of the converging laser beam decreases as it approaches the detector, at this point in the laser beam there is exactly the small number of particles that are necessary for analyzing their shape. Azimuthally (ray-like) located elements of the detector record fluctuations of scattered radiation, on the basis of which the computer program analyzes the shape of particles. The program allows to determine the elongation ratio for the $\times 50$ value of the previously measured distribution, and also to judge the "facetedness" of the particles. Figure 2 shows the shape of the microparticles of the "CoCr" powder.

Figure 2. Parameters of the shape of the powder microparticles "CoCr"

It was found that the elongation coefficient (elongation) of particles with a size of 44.128 $\mu m$ is 1.931.

The AFFRI DM-8 automated microhardness meter (according to Vickers) provides microhardness measurements in automatic mode with the construction of microhardness distribution curves. GOST 9450-76, measurement of microhardness by indenting diamond tips. The use of an automatic image analysis system PRECIDUR® allows manual measurements or fully automates the process of measuring microhardness. For the given device there is a certain set of commands with which help it is possible to set parameters of microindentation taking into account features of each specific research task. For example, you can specify the direction of indentation, specify the number of prints, the distance between them, the load on the indenter, indent on the weld, using the interpolation method, conduct studies of multiphase materials, etc. The built-in digital camera allows not only to visualize...
the surface of the sample on the computer monitor, but also to take photographs of residual prints after microindentation. Specifications and additional options: Vickers indiktor, memory is designed for 999 measurements, built-in function of unit conversion, corresponds to ISO, JIS and ASTM standards, common magnifications: 100×, 400×, automatic turret (facilitates the operator by automatically selecting an indentor and lenses ), the function of automatic return to the set position at the end of the working cycle.

Tests on the hardness of the samples on the surface and cross-section were carried out using an automatic microhardness analysis system DM-8 using the micro-Vickers method with an indentor load of 200 grams per ten prints with a free choice of the site of the injection in accordance with GOST 9450-76 (Measurement of microhardness by indenting diamond tips). The loading time of the indenter was 15 s. The results of the measurements are given in Table 1.

| Imprint number | Value |
|----------------|-------|
| 1              | 523   |
| 2              | 519   |
| 3              | 587   |
| 4              | 624   |
| 5              | 605   |
| 6              | 550   |
| 7              | 601   |
| 8              | 596   |
| 9              | 592   |
| 10             | 601   |
| Average value (units of measure) | 580 |
| HV             | 5684  |
| GPa            | 5.684 |

4. Conclusion
Based on the results of the conducted studies, it has been experimentally established that the microhardness of additive products obtained from electroerosive powders with an average particle size of 52.5 μm is 5.7 GPa.

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