Investigation of the elemental composition of the WNF-95 sintered powder alloy obtained by the electroerosive dispersion of waste in a carbon-containing liquid

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Abstract. The results of the study of the pressed and sintered electroerosive powder alloy WNF -95 are presented. Powder alloy WNF-95 was obtained by electrodispersion of shavings from waste tungsten-nickel-iron alloy in kerosene. Sintering of electroerosive powder alloy WNF-95 was carried out by the method of spark plasma sintering. The aim of this work was to study the elemental composition of the WNF-95 sintered powder alloy obtained by electrodispersion of waste in kerosene. It has been established that the elemental composition of the sintered sample obtained by sintering the electroerosive pseudo-alloy WNF-95 is comparable to the elemental composition of the initial powder, which indicates the efficiency of its use for the manufacture of tungsten-nickel-iron alloys.

1. Introduction
The creation of heavy tungsten-nickel-iron alloys (WNF) with improved mechanical characteristics is currently the subject of intensive research, due to their widespread use in the aerospace industry, automotive, medicine, construction and other fields. The production of such alloys requires the use of initial high-quality powders in the technological process, the production method of which determines the quality and cost of finished workpieces and products [1-10]. Therefore, it is relevant to reduce the cost of powder materials and improve their quality through the use of progressive, environmentally friendly technological processes, such as the method of electrodispersion [11-15]. The advantage of electroerosive dispersion technology is the use of waste as dispersible materials, the cost of which is much lower than the known industrially manufactured components, as well as a significantly lower energy consumption of the process. When obtaining WNF alloys using powder metallurgy technology, an important criterion for the suitability of powders is the elemental composition of sintered billets and products. The aim of this work was to study the elemental composition of the WNF-95 sintered powder alloy obtained by electrodispersion of waste in kerosene.

2. Material and methods
The process of electroerosive dispersion was carried out at a voltage on the electrodes U = 100 ... 110 V, the capacitance of the discharge capacitors C = 50 μF, and a pulse repetition rate ν = 90 ... 160 Hz. Waste of the WNF-95 alloy was placed in a reactor for electroerosive dispersion filled with a working liquid - kerosene; electrodes connected to an electroerosive installation were lowered into the reactor (patent for invention of the Russian Federation No. 2449859). Under the influence of short-term electric charges between the electrodes, a breakdown of the working fluid occurs with the formation of...
fine powder particles. The chemical composition of the obtained electroerosive powders of the WNF-95 alloy is as follows: nickel 3.34%, iron 1.53%, carbon 0.15%, oxygen 0.1%, tungsten 94.98%.

The electroerosive powder alloy WNF-95 was sintered by the spark plasma sintering method using the SPS 25-10 system (Thermal Technology, USA). The starting material was placed in a graphite matrix placed under a press in a vacuum chamber. Electrodes, integrated into the mechanical part of the press, supply an electric current to the matrix and create spark discharges between the sintered material particles, ensuring intense interaction. The modes of spark plasma sintering of the electroerosive powder alloy WNF-95 are shown in Figure 1.

Figure 1. Sintering modes of electroerosive powder alloy WNF-95 by the method of spark plasma sintering.

The surface of the sample was ground with metallographic paper with coarse (No. 60-70) and fine grain (No. 220-240), periodically rotating the sample by 90°. The abrasive particles were washed off with water and subjected to polishing on a wheel with suspensions of metal oxides (Fe₃O₄, Cr₂O₃, Al₂O₃). After reaching a mirror finish, the surface of the section was washed with water, alcohol, and dried with filter paper.

X-ray spectral analysis of the obtained samples was performed using an EDAX energy-dispersive X-ray analyzer (Figure 1) built into a QUANTA 600 FEG scanning electron microscope.

With the help of scanning electron microscopy, it was possible to carry out direct analysis of powder particles with a sufficiently high resolution. With a scanning electron microscope we could observe a three-dimensional image of the structure under study at a large depth of focus (Figure 2).
Figure 2. A scanning electron microscope «QUANTA 600 FEG».

The fractional composition of the W-Ni-Fe powders was studied using an Analysette 22 NanoTec laser analyzer (Figure 2).

3. Results

To eliminate this fact, a research and educational center "Powder Metallurgy and Functional Coatings" was created in Southwest State University, where young scientists carry out advanced researches and developments, aimed at obtaining multifunctional materials, including nanomaterials from waste of conducting materials, using a resource- and energy-saving, non-waste and environmentally friendly technology of electroerosive dispersion (EED), protected by a patent for an invention [11-18].

X-ray microanalysis was carried out to determine the elemental composition of a sintered sample of VNG-95 electroerosive powder on an EDAX energy dispersive X-ray analyzer built into a QUANTA 600 FEG scanning electron microscope. The points of analysis are shown in Figure 3. Spectra of characteristic X-ray radiation were obtained at two points and over the sample surface (Figure 4-6). The averaged elemental composition of a sintered sample obtained from WNF-95 powder electroerosive pseudo-alloy is given in Table 1.

Figure 3. X-ray microanalysis points.
**Figure 4.** X-ray spectral microanalysis of a sintered sample obtained from powder electroerosive pseudo-alloy WNF-95 at point 1.

**Figure 5.** X-ray spectral microanalysis of a sintered sample obtained from powder electroerosive pseudo-alloy VNG-95 at point 2.
Figure 6. General X-ray spectral microanalysis over the surface of a sintered sample obtained from a powder electroerosive pseudo-alloy VNG-95.

Table 1. Average elemental composition of a sintered specimen obtained from powder electroerosive pseudo-alloy WNF-95.

| Point | Element | Weight, % |
|-------|---------|-----------|
| 1     | W       | 99.55     |
|       | O       | 0.45      |
| **Total** |       | **100**   |
| 2     | W       | 94.68     |
|       | Ni      | 3.28      |
| **Total** |       | **100**   |

The following general elemental composition of the sintered specimen obtained from the WNF-95 powder electroerosive pseudo-alloy is established: tungsten 94.68%, nickel 3.28 %, iron 1.83 % and oxygen 0.21 %. The results obtained indicate that the elemental composition of the sintered sample obtained by sintering the electroerosive pseudo-alloy WNF-95 is comparable to the elemental composition of the initial powder.

4. Conclusion
The paper considers an important scientific and practical problem, aimed at the restoration and surface hardening of worn car parts, based on the use of electroerosive materials, including nanoscale materials.
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