Hard Alloy Synthesis from Tungsten-containing Electroerosion Powders of Micro- and Nanometric Fractions

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The article presents the results of the studies of the composition, structure and properties of the hard alloy produced using hot-pressing technique with the high current passage from the powder produced using electroerosion dispersion of sintered hard alloys wastes in lamp kerosene and distilled water.

Keywords: Hard alloy wastes, Electroerosion dispersion, Lamp kerosene, Distilled water, Tungsten-containing powder, Synthesis, Properties of hard alloy.

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1. INTRODUCTION

Tool hard alloys used in the modern engineering industry are produced on the basis of tungsten carbide, titanium carbide, tantalum carbide, or combinations of these carbides, sometimes using of niobium, vanadium, chromium carbides as a minor additives. Cobalt, and sometimes nickel and iron are used as binding materials in the alloys. Hard alloys are produced by pressing blend and sintering pressed blend products.

Carbides, nitrides, borides and silicides of refractory metals have a high melting point (2000-3800 °C), very high hardness, second in hardness only to diamond and carbides of boron and silicon, high modulus of elasticity; they are chemically resistant to acids, alkali and water vapour; they have distinct metallic properties, in particular high thermal and electrical conductivity, and the majority of them have particular crystal structure typical of the so-called 'interstitial phase' [1-7].

Currently, of compounds mentioned mainly carbides, mostly tungsten monocarbide WC, titanium carbide TiC, and tantalum carbide TaC have a wide practical application in manufacturing sintered hard alloys.

Hard alloys are not subjected to large noticeable deformation at low temperatures and hardly susceptible to elastic deformation: the elastic modulus value is 500-700 hPa, i.e. higher than that of all known in engineering materials. Sintered hard alloys are also highlighted as having very high degree of hardness for crushing, up to 6 hPa. However, the values of bending and impact strength bounds of these alloys are relatively small: $\sigma_{bend} = 1 \div 2{,}5$ hPa, $\sigma_{imp} = 0.5\ \sigma_{bend}$, $a_{H} = 0{,}02 \div 0{,}06$ MJ/m^2 [1-7].

At present, one of the main problems of using hard alloys is their wastes processing and further use. Repeated attempts to remove tungsten from the composition of hard alloys (due to its high cost) failed because none of the high-melting compounds does not provide such high strength characteristics. Therefore, the problem of hard alloys wastes processing is currently very topical.

The characteristic features of major existing industrial hard alloy waste processing technologies are large tonnage, energy intensity, large industrial areas, and often environmental problems (waste water, emissions). Method of electroerosion dispersion (EED) is one of the most promising methods for producing powder from almost any current-conducting metal including hard alloys. This method has relatively low energy costs and is environmentally friendly [8-14].

The objective of this work is the synthesis of hard alloy from tungsten-containing powders of micro- and nanometric fractions produced using electroerosion dispersion in lamp kerosene and distilled water.

To carry out the planned research the hard alloy plates of grade T15K6 were chosen. Lamp kerosene and distilled water were used as working fluids.

When solving the defined tasks modern methods of testing and research were used:

− hardness was determined using the test micro-Vickers machine "Instron 402 MVD";

− pressing of the powder was carried out in the hot pressing unit by direct passage of electric current;

− mechanical processing of the sintered samples was carried out using an automatic high-precision bench-type cutting-off machine "Accutom-5" and the grinding and polishing machine "LaboPol-5";

− density was determined using helium densimeter Micromeritics AccuPic II 1340;

− bending strength bounds were determined using a universal testing floor-type electromechanical testing machine "Instron 300LX-B1-C3-J1C";

− metallographic research (microstructure, porosity, grain size) was carried out using an optical inverted microscope "OLYMPUS GX51", equipped with a system for automated image analysis "SIMAGIS Photolab" etc.

2. EXPERIMENTAL RESULTS AND DISCATIONS

The experimental results of the hard alloy produced using hot-pressing technique with the 3 minute high current passage in vacuum from the powder produced using electroerosion dispersion of T15K6 hard alloy waste on the composition and properties of the initial blend are presented. The modified hot-pressing technique in which an electric current passes directly through the mold and the stock material, rather than through an external heater, is used as the basis of the process. A very fast heating and extremely short work-cycle time are achieved using pulsed electric current and the so-called 'spark plasma effect'. This allows suppressing the grain growth and obtaining equilibri-

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um state, which provides opportunities for creating new materials with previously unavailable compositions and properties, with submicron or nanoscale grains, as well as composite materials with unique or unusual composition.

The results of the study of hard alloy porosity are shown in Table 1.

Table 1 – The study of hard alloy porosity

Characteristics	Hard alloy produced		
	from the powder in water	from the powder in kerosene	from the standard powder
Number of fields of vision	5	5	–
Area of analysis, μm	317775,8	317295,4	–
Porosity, %	9,18	up to 0,1	up to 1

It is noted that the hard alloy produced using hot-pressing technique with the high current passage from the powder produced using electroerosion dispersion of T15K6 hard alloy waste has the porosity 9.18 times larger than the powder produced in distilled water, and the absence of porosity in the products made from the powder produced in lamp kerosene.

It is known that mechanical properties of hard alloy (transverse bending strength, impact strength, fatigue strength) decrease with increasing porosity. This decrease is due to the stress concentration in pores, which are the places of the crack initiation and propagation at loading.

The results of the study of the hard alloy grain size are presented in Table 2.

Table 2 – The study of the hard alloy grain size

Characteristics	Hard alloy produced		
	from the powder in water	from the powder in kerosene	from the standard powder
Number of measurements	26	26	–
Minimum length, μm	0,19	0,12	–
Maximum length, μm	2,71	1,27	–
Average length длина, μm	1,07	0,71	1,5…3,0

It is noticed that the grain size of the hard alloy produced using hot-pressing technique with the high current passage from the powder produced using electroerosion dispersion of T15K6 hard alloy waste is 2-3 times smaller compared to the hard-metal products produced from the standard powder according to the industrial technology. With decreasing of the tungsten carbide grain size the alloy hardness increases but the strength decreases.

The results of the study of hard alloy density are shown in Table 3.

Table 3 – The study of hard alloy density, g/cm^3

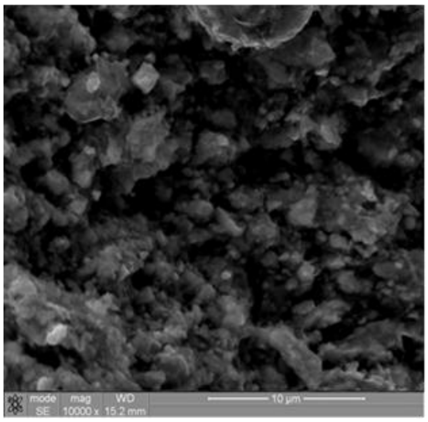
Characteristics	Hard alloy produced		
	from the powder in water	from the powder in kerosene	from the standard powder
After pressing	7,8	8,16	–
After sintering	11,4	12,35	11,5

It is noticed that the density of the hard alloy produced using hot-pressing technique with the high current passage from the powder produced using electroerosion dispersion of T15K6 hard alloy waste is by 7.4 % higher compared to the hard alloy produced from the standard powder according to the standard technology.

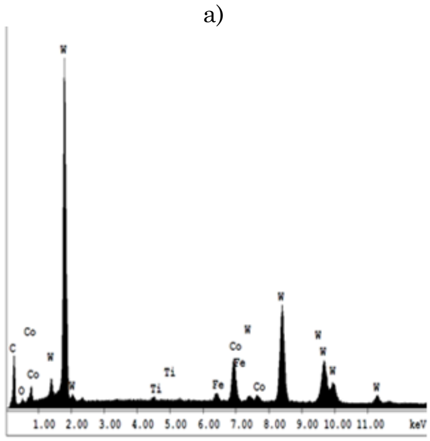
The results of the study of hard alloy bending strength bounds are shown in Table 4.

Table 4 – The study of bending strength bounds of hard-metal products, MPa

Characteristics	Hard alloy produced		
	from the powder in water	from the powder in kerosene	from the standard powder
Values	88,23740	1876,27991	1127…1180



a)



b)

Fig. 1 – a) Microstructure and b) composition of the elements of the hard-metal products manufactured from hard alloy powder produced using electroerosion dispersion in water

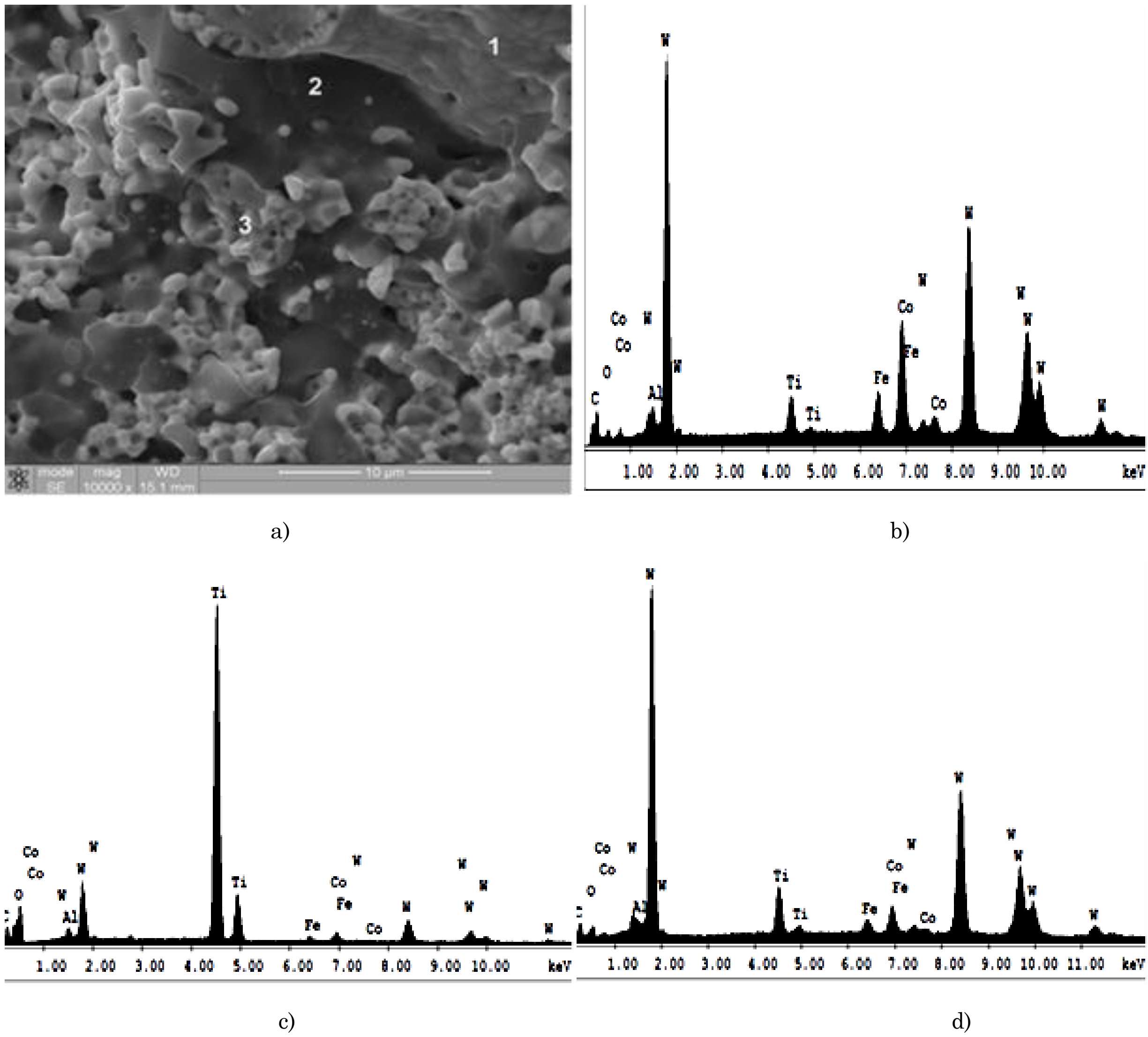


Fig. 2 – Microstructure a) and composition of the elements of the hard-metal products manufactured from hard alloy powder produced using electroerosion dispersion in kerosene at the point: b) 1; c) 2; d) 3

It is noted that the hard alloy produced using hot-pressing technique with 3 minute high current passage at temperature of 1,320 °C from the powder produced using electroerosion dispersion of wastes of sintered hard alloy of T15K6 grade in lamp kerosene has 1.7 times greater bending strength compared to the hard alloy produced from the standard powder according to the industrial technology, because the first one has finer grain.

The results of the study of the microstructure and the composition of the elements of the hard-metal products manufactured using hot-pressing technique with 3 minute high-current passage from the powder produced using electroerosion dispersion of wastes of T15K6 hard alloys is shown in Fig. 1 and Fig. 2.

The results of the study of hard alloy products hardness are shown in Table 5.

It is noted that the hard alloy produced using hot-pressing technique with high current passage from the powder produced using electroerosion dispersion of the wastes of T15K6 hard alloys has the hardness 1.5-3.0 times less than the hard alloy produced from the standard powder produced according to the industrial technology.

Table 5 – Hardness of hard alloy products, HV at loading of 50 H

Test material	Average / Mean value
Hard alloy produced from the powder produced using electroerosion dispersion in distilled water	554
Hard alloy produced from the powder produced using electroerosion dispersion in lamp kerosene	1729
Initial hard alloy T15K6	1141

3. CONCLUSIONS

1. It is found that the hard-metal products produced using hot-pressing technique with 3 minute high current passage at temperature of 1,320 °C from the powder produced using electroerosion dispersion of the wastes of sintered hard alloys of T15K6 grade in lamp kerosene compared to the hard-metal products produced from the standard powder according to the industrial technology have the following characteristics:

– they have almost no porosity;
– they have 3 times less grain size;
– their density is 7.4 % higher;
– their bending strength is 1.7 times higher;
– their hardness is 1.5 times higher.

2. It is found that the hard-metal products produced using hot-pressing technique with 3 minute high current passage at temperature of 1,320 °C from the powder produced using electroerosion dispersion of the wastes of sintered hard alloys of T15K6 grade in distilled water compared to the hard-metal products produced from the standard powder according to the industrial technology have the following characteristics:

– they have a lot greater porosity;
– they have 2 times less grain size;
– they have almost equal density;
– their bending strength is 12.8 times less;
– their hardness is 3 times less.

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