NEW MANUFACTURING TECHNOLOGY OF CARBIDE PLATES USED IN METAL MACHINING

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Abstract - The article discusses the results of research work on an innovative technology for the manufacture of carbide blades for metal-machining tools from ultrafine tungsten powders.
Analysis of the results of the study showed that the shape and dimensions, the level of residual internal stress in the cutting part of the machining tools, as well as the granulometric composition of tungsten powders affect the resistance of carbide plates. In the studies carried out, special attention was paid to the study of the stress state of the working elements. The stress state of an insert made of a hard alloy (five-fold difference in thermal expansion coefficients) and a molybdenum alloy (three-fold difference in thermal expansion coefficients) steel 40XNML leads to the creation of a state of all-round compression in the insert upon cooling.

Keywords: Powder, Composition, Granulometry, Size, Shape, Structure, Hard alloy, Metal machining tool, Cutting part.

1. Introduction

There are many machine-building enterprises in Uzbekistan, where metal cutting is one of the important tasks of the development of the economy of the Republic of Uzbekistan. Replacement of metal cutting tools with newer ones leads to an increase in labor productivity, therefore it is important to increase the durability of these tools, ensuring them without replacement during the entire machine time.

The results of research conducted in many countries indicate the real possibility of using refractory metals for the manufacture of carbide tools, tools, and other materials with increased performance characteristics. However, more detailed studies on the implementation and modeling of the composition of hard alloys to improve mechanical properties have shown that tools for cutting metals with carbide plates using dispersed powders of refractory metals, in particular composites, have not yet been sufficiently studied. In this regard, it is of particular importance to study the morphology and dimension of dispersed powders obtained by various methods.

The replacement of large powders with dispersed ones in the technological process of processing makes it possible to reduce the sintering temperature of blanks and makes it possible to obtain a more homogeneous and fine-grained structure of sintered products. Including carbide plates, which are used in metal cutting tools.

Since the republic gained independence, the production of powders of refractory metals and hard alloys from local raw materials has been established in our country, and special attention is paid to the localization of the production of carbide parts and products that are competitive in the world market. In this regard, significant results have been achieved in improving the quality of products for the manufacture of carbide parts and optimizing heat treatment modes, including the possibility of obtaining powders of refractory metals, hard alloys with the desired properties have been developed, and the cost of products obtained by powder metallurgy has been reduced. Along with these, there was a need for improvements in energy-saving technologies that ensure the competitiveness of machine-building enterprises. The development action strategy of the Republic of Uzbekistan separately notes the task "improving the competitiveness of the national economy, reducing the energy intensity and resource intensity of the economy, the widespread introduction of energy-saving technologies into production" [1].

To accomplish this task, it is important to improve the quality and competitiveness of products using energy-saving technologies based on improving the production processes of carbide tools, parts and products.

In the world, much attention is paid to improving the production processes of carbide tools, parts and products. Among other things, the main factors in the development of this sphere are the optimization of the composition and improvement of the

manufacturing technology of existing hard alloys; the development of new compositions [4, 5].

The development and improvement of technological processes are inextricably linked with the use of hard alloys, which contributes to a significant increase in the operational characteristics of the tool and labor productivity. One of the promising areas of improvement of hard alloys is the development of technology that provides simultaneous improvement of properties such as viscosity and wear resistance, strength, and ductility, in comparison with traditional ones. It is the combination of these properties that leads to the durability of metal machining tools [4,5].

The required combination of properties will have an alloy with an increased polydispersity component. It is assumed that large grains of the phase will provide plasticity, and small grains – increased the wear resistance of the alloy. Hardness, yield strength, and compressive strength increase with an increase in the proportion of fine grains in the alloy structure. The bending strength practically does not depend on the change in the ratio of large and small grains in the mixture and alloys and only slightly decreases with the highest content of small grains. The ultimate plastic deformation with an increase in the fraction of fine titanium carbide grains in the mixture to 40% practically does not change, and with an increase to 60% decreases slightly (10%). Analysis of the data obtained shows that the most advantageous combination of plasticity and wear resistance are alloys with a ratio of coarse and fine fractions of 60:40 [7].

2. Materials and Methods

The object of the study is hard alloys – grades VK6, VK8, VK10, VK11C (GOST 3882-74) and carbide plates for metal cutting tools.

The subject of the study is the technology of manufacturing carbide plates for the cutting part of metal-cutting tools in machine-building enterprises.

In the research work, methods of metallography analysis, X-ray diffraction, tensometric studies of internal residual stresses, methods of measuring macro- and microhardness of samples, heat treatment modes, and methods of testing full-scale finished products were used to study the structure of carbide plates.

3. Results and Discussion

In machine-building enterprises, many different tools are used for machining metals. The working part of the machining tool is mainly made of hard alloys of various grades of the VK, TK, and TTK group, the holders of the machining tools are made of steels of various grades, mainly carbon tools steels.

The working part of the machining tool and carbide plates are installed by soldering, casting, and mechanical methods.

New modes of heat treatment of bimetallic composite have been developed and proposed. To study changes in the properties and stress state of the composite, intermediate isothermal exposure was carried out at a temperature of 280 ˚C and 350 ˚C for 1, 3, 5, and 10 minutes, in the area of martensitic and bainitic transformation of steel 35 XGCL. This was done to study the effect of the initial structure of the bearing base before the second phase of recrystallization on the stress state of the working element of the tool and its performance indicators. This method will increase the durability of the tool by 1.5-2 times, as well as reduce the cost of manufacturing the tool by 2 times, and is a resource-saving technology [9].

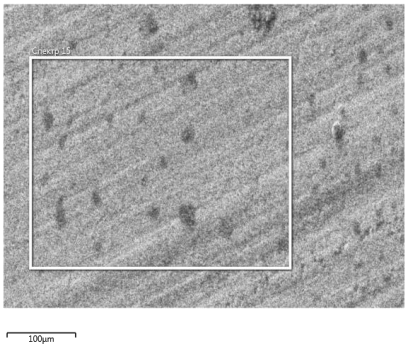


Figure 1: An electronic image of a hard alloy

Table 1. Chemical composition of the hard alloy

Element	Weight.%	Sigma Weight.%
C	9.45	0.44
O	2.49	0.19
Na	0.41	0.09
Si	2.28	0.23
P	0.65	0.15
Cl	0.40	0.13
Co	4.41	1.15
W	79.91	1.08
Total:	100.00	

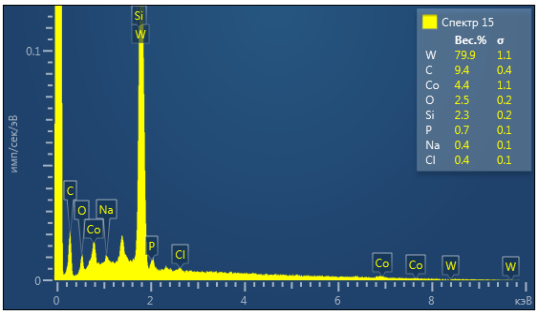


Figure 2: Spectrogram of the chemical composition of a hard alloy

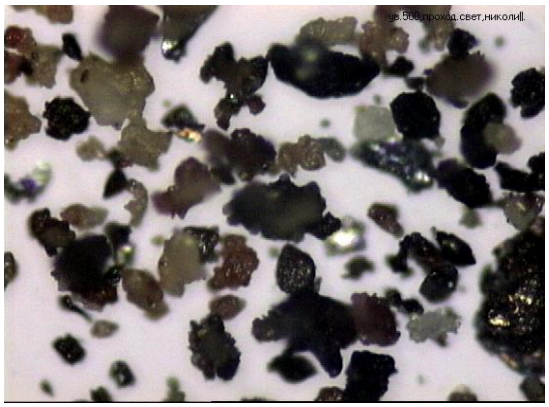


Figure 3: View of WC powder under a microscope, x2500

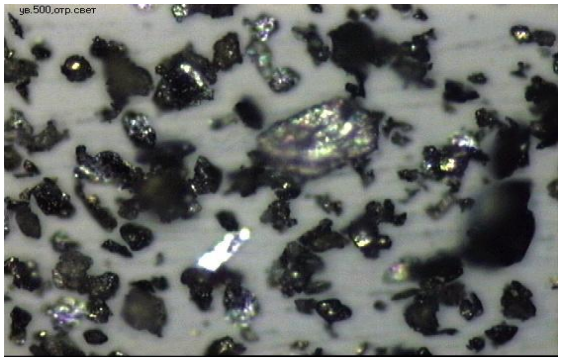


Figure 4: Morphology and dimension of WC powder grains, x500

The authors of the works propose a new approach to the manufacture of these incisors. A new carbide material is proposed for the cutting part of the tool, that is, a multicomponent alloy based on tungsten - a product of powder metallurgy. The tool body is cast from carbon tool steel grade U8. Cu-Ni alloy is used as an intermediate layer.

The macroscopic characteristics of samples of UDP tungsten (Fig. 3.) and tungsten carbide (Fig. 4.) have been studied.

X-ray studies were carried out on a "Panalytical Empyrean" diffractometer equipped with a Cu tube ($K_\alpha 1$=1.5406A) available at the Centre of Advanced Technologies under the Ministry of Innovation Development of the Republic of Uzbekistan. Measurements were made at room temperature in 0.01 degree steps in scan mode in the range of 5˚ to 90˚, on a turntable at 2θ angular intervals.

The external morphology and dimensions of the obtained powders were measured on the equipment available at the Centre of Advanced Technologies under the Ministry of Innovation Development of the Republic of Uzbekistan, and the surface morphology and microstructure of the powders were studied using a SEM-EVO MA 10 scanning electron microscope manufactured in Carl Zeiss, Germany. This device is intended for microscopic analysis of inorganic materials powders, particles, fibres, and microstructures on the surface of metals, semiconductors and thin films, structure of defects on the surface. Scanning electron microscope studies were carried out as follows:

In the process of sample preparation, a metal alloy holder with double-sided adhesive aluminium foil was installed on the object table of the microscope. The powder was poured onto the foil and then blown with air. The slide stage was then placed in the working chamber of the microscope where the air was suspended to create a vacuum. To perform the measurement, a voltage of 10 kV is applied to the filament in the SE detection mode. The working distance was 8.5 mm. Images at scales of 20-100 μm were obtained using Smart SEM programming software.

In short, to get a high-quality picture:

- a voltage of 10 kV is supplied to the filament of the electron generation device of the microscope;
- the working distance between the sample and the focused electron beam should be 8.5 mm;
- The electron beam is recorded through SE1. A special identification number is assigned to each picture.

To form the optimal structure of hard alloys, it is necessary to choose a metal binder that provides good tightening of a part of titanium carbide, the absence of significant solubility of the solid phase in the bundle, the third phases during sintering, etc.

In this operation, a continuous-acting pusher vacuum electric furnace CTV-5-23-1,5/16 G is used. It was found that the more binder metal in the alloy, the higher the dispersion of the refractory component, and the lower the content of tungsten carbide, the lower the sintering temperature. For this process, the electric furnace provides the required sintering temperature of 1450 °C and a sintering time of 1.5-2 hours, and a vacuum depth of the order of 1-10 Pa [11].

Based on the research work carried out on the development of technology for the manufacture of carbide plates for metal cutting tools, the following grade of hard alloy VK11C with a density of 14.1-14.5 g/cm^3, a hardness of 86.5 HRA and chemical composition of 89% WC, 11% Co and a new multi-component alloy based on tungsten is proposed. Below are samples of cast bimetallic metal-cutting tools using UFP tungsten (Fig.5-9).

The authors [9] have developed a technology for the production of dies for wire drawing from cast bimetallic composites. The working element of the composite is an insert made of molybdenum alloy of the MoTiC system, an intermediate layer in the form of a bandage made of copper and nickel wire with a ratio of 3:2, the bearing base is cast structural steel 40XNML. Cast bimetallic composites (CBC) should ensure the high performance of the tool. Optimization of the technological parameters of the intermediate layer was carried out using the method of mathematical planning of experiments. Die tools and tooling, especially for working at high temperatures and pressures, largely determine the

efficiency of production in mechanical engineering. That is why the development of new materials and technologies designed to reduce the complexity of manufacturing and reduce the consumption of scarce tool materials is an urgent problem in modern mechanical engineering [10].

In connection with the above, a new molybdenum alloy, the Mo-TiC system, has been developed, the manufacturing technology of which is based on powder metallurgy methods, which is undoubtedly more economical and technologically more efficient than cast eutectic alloys of the same system. The composition of the cast eutectic alloy of the Mo-TiC system: 87% Mo, 13% TiC.

Figure 5: Cast bimetallic disk three-sided machining tool*s (diameter D= 100 mm, B=6, 14, 12 mm)*

Figure 6: Cast bimetallic metal-cutting single-blade knife of a combined milling tool

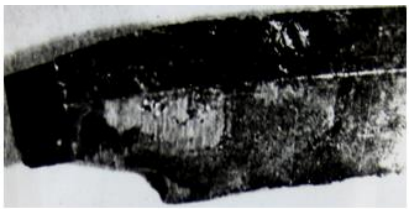


Figure 7: Cast Bimetallic metal-cutting single-blade through-hole machining tool

Figure 8: Cast Bimetallic metal-cutting single-blade Undercut machining tool

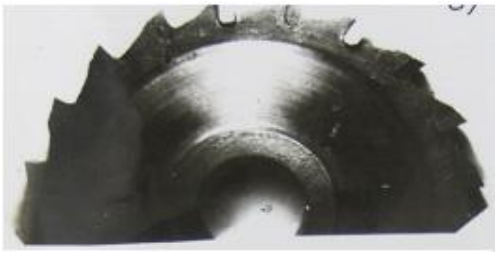


Figure 9: Cast bimetallic multi-blade tool: grooved milling tool

The high Mo content in the cast eutectic alloy makes it a little more expensive, and the production of a cast eutectic alloy of the Mo-TiC system is a labor-intensive and energy-intensive process [9]. In the developed sintered molybdenum alloy, the ratio of Mo and TiC is 50/50%. In addition, the following additives were introduced into the alloy to improve operational and technological properties: Fe, Ni, W, and LaB_5. Physico-mechanical, technological and other properties of the sintered molybdenum alloy of the Matic system are superior to the foundry eutectic alloy of the same system. Based on the results of the conducted composition studies.

Comparative durability tests of bimetallic drills were compared with the same type of assemblies (GOST 25524-82). The tests were carried out on a horizontal drilling machine 2M57. The durability measure defines the drilling period until the cutting edge is blunted. The test results are presented in Table 2.

Table 2. The results of comparative tests on the durability of prefabricated and bimetallic feather drills when drilling various materials

Methodof obtaining	Mode TO	Cutting mode		Durability T, min		Note
		V	S	Steel 45	Steel 12X1810T	
Prefabricated feather GOST 25525-82	Mode TO	25,3	0,52	70	–	Durability T – arithmetic mean expectation from the sample n> 25 at the significance level is equal to 0,05
Casting	Spec. TO	25,3	0,52	89	–	
Prefabricated feather GOST 25525–82	Stand. TO	28,8	0,50	–	30	
Casting	Spec. TO	28,8	0,50	–	37	

The following drilling modes are selected: for steel 45, the cutting speed is V = 25.3 m/min; the feed is S=0.52 mm/rev. For steel 12X1810T: cutting speed – V=28.8 m/min; feed – S= 0.50 mm/rev. A comparison of the results of durability tests shows that the durability of bimetallic drills is 25-30% higher than the durability of similar variants.

When working in cast bimetallic compositions, the main danger is the displacement of the cutting part relative to the body.

Therefore, the ultimate shear strength was taken as the main criterion for the performance of composites.

The test results are presented in Table 3.

Table 3. The results of studies on the static strength of the joint and the stress state of the working element of matrices for the synthesis of super hard materials, depending on the method of manufacture before and after heat treatment

Tool type	Mode of production	Turning Mode	Strength σ_{cg},MPa	Internal residual stresses, MPa	Note
Matrix for STM synthesis	Pressing	Without TO	100-120	80-100	N- arithmetic mean values of the mathematical expectation for the sample n=5 significance α=0.05
Matrix for STM synthesis	Pressing	Standard TO	150-180	110-120	
Matrix for STM synthesis	Cast	Without TO	200-240	180.-240	
Matrix for STM synthesis	Cast	Standard TO	250-280	450-500	

Samples of plasma carbide tools based on tungsten UFP are manufactured in the production conditions of JSC "UZKTJM". Hardness, density, and bending strength were determined on carbide samples. The results of the study under laboratory conditions are shown in Table 4. Hardness and flexural strength tests were carried out on the manufactured plasma powder samples and their specific gravity and densities were determined.

The test results showed that the hardness of the prototypes averaged 89.5 HRC; specific gravity 13.52 g/cm^3 and bending strength in the range of 135-140 kGf/mm^2.

Table 4. Research results

№						
	Hardness ZIP model TK – 2M GOST 13407 – 57 № 1793					
	Machining tool - plate, HRC		Multi-faceted removable machining tool, HRC		Spinneret, HRC	Fillet, HRC
1	89,2		89,2		89,2	89,9
2	89,1		89,2		89,3	89,7
3	89,3		89,4		89,2	89,8
№						
	Specific gravity – density, g/sm^3 TYPWA – 33 Nr 57751 Made in Poland					
	Pentahedral removable machining tool		Triangular removable machining tool		Spinneret	
	Air	Water	Air	Water	Air	Water
1	12,920 g	11,950 g	18,940 g	17,570 g	32,230 g	29,840 g
2	Σ 950 g		Σ 1370 g		Σ 2390 g	
Density, ρ g/sm^3						
1	13,45		13,82		13,57	
2	Average ∑ 13,55 g/sm^3					

Experimental batches of samples of metal-cutting and shaping tools were made (Figure 10 and 11) based on UDP tungsten.

The following batches of samples were made: forming tool:

Form 8 GOST 9457-75; metal-cutting tools. Forms 13 GOST 17153-82, Forms 07.57 GOST25425–85, Forms 110114-110 408 GOST190 55-80, Forms 02, 114-100508 GOST19048–80 and stacks.

Samples of plasma carbide plates of metal-machining tools, manufactured in an amount of 4 pieces each within the framework of agreements 41/10 of 12.04.2010 and 25/10 of 12.04.2010 with JSC "UZKTJM" and which were tested in the workshops of SJSC "TAPOICH" from 06.06.2012 to 08/24/12.

Comparative tests for the durability of metal-cutting plates when processing samples made of steel 45 (cutting modes V=90 m/min; S= 0.3 mm/mod.; t=1 mm), when processing cast iron from 20 steel (cutting modes V=60 m/min; S= 0.2 mm/mod.; t=2 mm) the resistance of the incisors was 0.8-1.2 times greater.

As a result of the tests carried out on processing with hard alloy machining tools, the durability of plasma plates turned out to be 1.06–1.40 times greater than standard samples made of 45 steel, and cast iron of 20 – 1.22–1.80, respectively [11].

a)

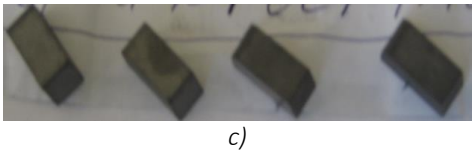
b)

c)

Figure 10: Samples of carbide metal-shaping tools: a) Drills for hard-to-work materials; b) Milling tools; c) Drawing dies

a)

b)



c)

Figure 11: Samples of carbide metal-machining tools: a) and b) Replaceable polyhedral plates; c) *Plates soldered for machining tools.*

All of the above samples from the proposed new sintered powder multicomponent alloy based on tungsten were manufactured within the framework of agreements with the Research and Production Association for the production of hard alloys and rare metals at JSC "AGMK" and passed pilot tests for density, hardness, bending strength, at the experimental industrial base of LLC "TURONABRAZIVE" and in the conditions of a joint venture "SPZ-BEARINGS", in the period 2015-2016 years [12-17].

4. Conclusions

Based on the results of theoretical and experimental studies and analysis of the results obtained, complex scientific, technical, and technological techniques and recommendations are proposed to determine further ways of developing high-tech processes in mechanical engineering, contributing to the development and expansion of scientific research, as well as important for the branches of mechanical engineering and the economy as a whole.

Based on the research work carried out on the technology of manufacturing carbide plates for the cutting part of metal-machining tools of machine-building enterprises of the republic, the following conclusions are presented:

The technology developed jointly with the NGO for the production of hard alloys and rare metals at JSC "AGMK" was transferred to the production enterprise LLC "TURONABRAZIVE" and in the conditions of the joint venture "SPZ-BEARINGS".

As a result of the tests, the following effects were obtained:

1. A new carbide composition of the cutting part of the metal-machining tool was obtained together with LLC "TURONABRAZIVE";

2.The technology of manufacturing a multicomponent alloy based on tungsten – 40KHNM steel with an intermediate layer based on silver has been developed:

3. Heat treatment modes have been developed;

4. The developed and proposed new modes of heat treatment of bimetallic composite allowed to increase the service life of the machining tools by 1.2-1.3 times.

5. The durability of plasma metal–cutting plates turned out to be 1.06–1.40 times higher compared to standard ones, and the cast iron of the Sch 20 – 1.22-1.80, respectively.

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