CREATION OF SUPERHARD COMPOSITE MATERIALS BASED ON DIAMOND AND BORON NITRIDE

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Abstract - The article presents the results of research work on the creation of a superhard composite material based on diamond and boron nitride designed to equip metal machining tools and tools for various purposes operated under conditions of intense abrasive impact and significant dynamic loads. The analysis of the results showed that the service life of the plates of metal machining tools increases by 2-3 times. Based on the results of theoretical and experimental research and analysis of the results obtained in the conditions of TURON ABRASIVE LLC, comprehensive scientific, technical and technological methods and recommendations have been 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 having important significance for the mechanical engineering industries and the economy as a whole.

Keywords: Superhard composite material, Diamond, Boron nitride, Durability, Wear resistance.

1. Introduction

Scientific and technological progress, increasing labor productivity, improving the quality of products, reducing the cost of production, saving labor and material resources largely depends on the use of composite materials containing synthetic superhard materials in combination with metals and alloys.

As a result of research work in the conditions of «TURON ABRASIVE» LLC, a superhard composite material based on boron nitride was proposed, designed to equip the working part of metal machining tools for various purposes operated under conditions of intense abrasive impact and significant dynamic loads. Materials of this class are tvesal, which is a composition of fine synthetic diamond powders distributed in an orderly manner in a hard alloy of tungsten group based material.

There are many machine-building enterprises in Uzbekistan, where metal machining is one of the important tasks of the development of the economy of the Republic of Uzbekistan. Replacement of metal machining tools with newer ones leads to an increase in labor productivity. Therefore, it is relevant to increase the durability of these tools, ensuring that they are not replaced during the entire machine time.

The results of research conducted in many countries indicate the real possibility of using superhard composite materials for the manufacture of plates of metal machining tools for various purposes with increased performance characteristics. However, to improve mechanical properties, more detailed studies on the introduction and modeling of the composition of superhard composite materials have shown that tools made from dispersed powders of refractory metals, especially boron nitride composites, have not yet been studied in enough detail. In this regard, the study of the morphology and dimension of dispersed powders obtained by various methods is of particular importance. 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 plates made of superhard composite materials based on boron nitride.

The development action strategy of the Republic of Uzbekistan separately notes the task of "increasing the competitiveness of the national economy, reducing the energy intensity and resource intensity of the economy, widespread introduction of energy-saving technologies into production" [1-2].

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 plates for metal machining tools made of superhard composite materials based on boron nitride [3-5].

In the world, much attention is paid to improving the production processes of parts and products made of superhard composite materials. In particular, the main factors in the development of this sphere are the optimization of the composition and improvement of manufacturing technology, existing superhard composite materials, the development of new compositions [6, 7].

2. Materials and Methods

The object of research is superhard composite materials based on diamond and boron nitride and plates of metal machining tools.

The subject of the research is the creation of plates from superhard composite materials based on boron nitride for the machining part of metal machining tools for metal machining in mechanical engineering enterprises.

Research methods. In the research work to study the structure of plates made of superhard composite materials based on boron nitride, methods of metallography analysis, X-ray diffraction, methods of measuring macro- and microhardness of samples, processing modes and methods of testing full-scale finished products were used.

The superhard composite material based on diamond or boron nitride in the conditions of «TURON ABRASIVE» LLC is manufactured by powder metallurgy. This method has wide possibilities for the formation of certain, predetermined properties. Manufacturing of superhard composite materials based on diamond and boron nitride for metal machining tools for various purposes in this enterprise, much attention is paid to the preparation and processing of raw materials, preparation of powder charge, regular distribution of diamond or boron nitride in the volume of the cutting element, consolidation of structural elements with the formation of strong contacts between them. Usually, for a super-hard composite material based on diamond, durable diamond grains purchased from Asian countries are used. Strong single crystals of synthetic diamonds are selected when they are sorted by magnetic properties and classified by shape and surface roughness.

Sorting of synthetic diamonds is performed by flotation with the release of grains containing less than 0.2% inclusions. There is also ultrasonic treatment in the molten salts, where thermally fragile grains are destroyed.

The process of preparing diamonds includes degreasing the surface of the grains and applying metal coatings on them. A method of carburizing coatings to incomplete saturation is proposed.

For the production of superhard composite diamond-containing tool material, a mixture of carbide powders with alloying elements is used. The charge is prepared in mixers of the "drunk" barrel type system.

The charge used to form the non-working part of the products is a superhard composite diamond-containing tool material, granulated. To do this, the carbide mixture in the screw mixer is mixed with a 12% solution of synthetic rubber in gasoline. After drying, the prepared charge is wiped through a mesh on a vibrating screen.

Graphite molds are used to produce products from superhard composite tool material of a given configuration and size. Graphite molds largely determine the complexity of tool manufacturing and the stability of its properties. The use of graphite is due to its high strength and EG-0 graphite is used for the production of superhard composite tool material [8-9].

Molding of products consists in packing the charge into attachments, sequentially filling them into a mold and cold pressing.

The sintering process is carried out in a hydrogen medium of a two-zone furnace with a graphite heater. The temperature and duration of heating should exclude complete carburization of tungsten carbide to stoichiometric composition.

The fundamental difference between superhard composite materials and diamond tools is that the destruction of the material occurs due to the simultaneous impact of both diamonds and the carbide matrix. The hard alloy forms a crimping "bed" that helps diamonds to withstand significant dynamic loads.

The planned research will be aimed at studying the method of powder metallurgy for the creation of superhard composite tool material, which allow not only to directly use the method of powder metallurgy with the help of which to obtain a wear-resistant, impact-resistant structure, which will make it possible to apply this method:

- Industry;
- Mechanical engineering.

The purpose of the work is to create a superhard composite material for metal machining tools using powder metallurgy.

3. Results and Discussions

The combination of two tool materials with different properties in one composition makes it possible to increase the service life of tools by 2-3 times, under operating conditions of intense wear and significant dynamic loads [6, 7].

The reliability and operability of metal machining tools are mainly determined by the condition of the machining parts that are the most rapidly wearing out [10]. Increasing the durability of the machining elements of tools is one of the main and effective ways to increase the service life. This would guarantee to improve the quality of tools and at the same time cover the needs of the industry of the Republic of Uzbekistan by increasing durability.

The scientific work provides for analyzing and developing the creation of a superhard composite material by powder metallurgy for metal machining tools, which has no analogues in practice. This is, first of all, necessary for the machine-building industry of the Republic of Uzbekistan.

The main idea is stated and proved at relevant scientific conferences and in publications [11].

However, its specific solutions require analytical work to improve the results achieved, proposed in applications for the invention and publications on this topic.

A project is proposed that includes solutions to innovative investment and production and economic issues of the machine-building industry from the point of view of using new methods for obtaining metal machining tools.

The results of the work can be applied in other areas of industry for the production of any tools that require an increase in hardness and wear resistance [12].

There is sufficient reason to perform this work: a number of scientific papers on this topic have been completed and defended at conferences. This line of work has no analogues in the near and far abroad.

Analysis of the results showed that the service life of the plates increases by 2-3 times [13].

Thus, at the moment the following practical results have been obtained:

-theoretical analysis of the process of particle formation in a superhard composite material;

-morphology and structure of dispersed powders have been investigated. It is shown that the level of micro distortion of ultrafine powders is 2-3 times greater than that of standard;

-the influence of the annealing temperature in vacuum and hydrogen on the structure and phase composition of powders and their subsequent chemical activity is investigated;

-modes of pressing mixtures and sintering of plates made on the basis of superhard composite materials are proposed.

The task is to create a superhard composite material that provides an expansion of its range of applications by varying its composition and properties, for example, strength, hardness, wear resistance and other mechanical properties, as well as a method that makes it relatively easy to obtain such a material [14-16].

By the method of catalytic synthesis at high static pressures and temperatures from hexagonal phases of graphite (C) (Fig.1) small particles of cubic boron nitride were obtained (Fig. 2).

Using a similar technology, a modification of boron nitride BN was obtained from boron and nitrogen, resembling synthetic diamond in structure and properties. The crystal lattice is cubic, the hardness is slightly lower than that of diamond, but still very high: 40-45 GPa, i.e. more than twice as high as that of hard alloys, and almost twice as high as the hardness of machining ceramics. Polycrystalline cubic boron nitride (PCBN) is sometimes called "borazone", "kubanite", "elbor". The modulus of elasticity of boron nitride E = 700-800 GPa, the compressive strength is approximately the same as that of hard alloys: σ_{comp}= 2.5 – 5 GPa, and lower than that of hard alloys and polycrystalline diamonds, the bending strength: σ_b = 0.6-0.8 GPa.

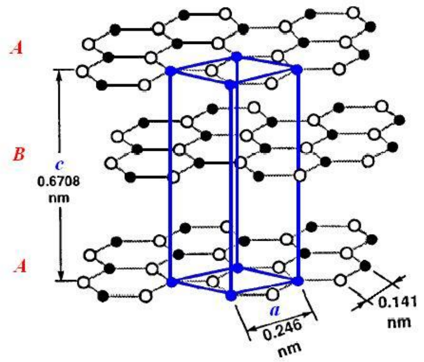


Figure 1: Hexagonal phase of graphite

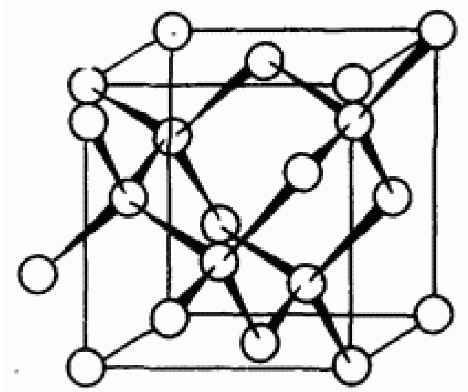


Figure 2: Crystal lattice of boron nitride

The heat resistance of cubic boron nitride is significantly higher than that of synthetic and natural diamonds: about 1000-1100 °C. For this reason, as well as due to the lower chemical affinity with carbon, cubic boron nitride is more effective than diamond and hard alloys in the finishing of steels by machining, especially when machining hardened steels of high hardness with small sections of the machining layer.

A technology for the production of superhard composite materials has been developed and a new charge composition for the machining part of metal-machining tools has been obtained in the conditions of TURON ABRASIVE LLC. A charge is prepared from diamond micro-powder of the ACM 28/20 brand (GOST 9206-80). To do this, a binder is added to the diamond powder – a 20-25% alcohol solution of phenol-formaldehyde resin of brand CF-010-A (GOST 18094-80) in an amount of 2-4% dry resin by weight of the diamond powder (Figure 3). The charge is thoroughly mixed and ground twice through a sieve with a mesh size of 0.25- 0.30 mm.

Modes for pressing mixtures and sintering in a high-pressure press have been developed for sintering PCBN and CBN blanks under the conditions of TURON ABRASIVE LLC. Forming of a sample with a diameter of 20-25 mm and a height of 2-3 mm is carried out by pressing the charge attachments using a metal mold. The suspension is placed in a mold and molded at

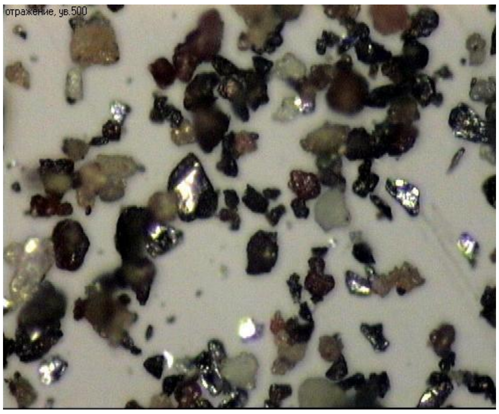


Figure 3: Macro image of powders used for the manufacture of superhard composite materials

room temperature with a force of 40-45 kN. Next, the molding is removed from the mold and kept in air at room temperature for 10 hours, and then dried at 70 °C for 1 hour and approved at 150 °C for 1 hour. The workpiece thus obtained contains 98% diamond mass and has a porosity of 47% volume.

Heat treatment of the work piece is carried out in vacuum (pressure - 0.1 mm Hg) at a temperature of 1550-1600 °C for 4 minutes. The specified heat treatment conditions allow graphitization of diamond particles by 14 wt. %.

The impregnation of the semi-finished product is carried out with a silicon - titanium alloy containing 12 wt. % titanium. Impregnation is performed by melting the specified alloy on the surface of the semi-finished product at 1550-1600 °C.

As a result, a product is obtained in the form of a tablet with a diameter of 20-25mm and a height of 2-3 mm from a diamond-containing material in which diamond grains are bound by a matrix containing silicon carbide, titanium carbide and a silicon-titanium alloy (titanium silicide).

Comparative tests of samples for wear by processing them with an ACHK-150x20x32 diamond wheel without coolant showed that the obtained samples have wear resistance almost equal to the wear resistance of similarly obtained samples, but pure silicon was used for impregnation (according to a known technical solution). The bending strength of the resulting material, measured by the maximum bending method, is 15-20% higher than the known material that does not contain titanium compounds.

Thus, the implementation of the claimed method makes it relatively easy to obtain diamond-containing materials in the form of parts of complex shapes and large dimensions. The use of silicon alloys provides an intensification of the impregnation process of the semi-finished product. At the same time, due to the addition of other compounds formed during the implementation of the method to the composition of the material, the obtained materials have a wider field of use due to the possibility of choosing compositions for optimal erosion and abrasive resistance. In addition, the presence of adhesive-active metals in the material facilitates their soldering during the manufacture of tools, and also increases the durability of tools by 2 times compared to analogues (Figure 4).

Figure 4: Micrography of soldered plates by superheating (x800)

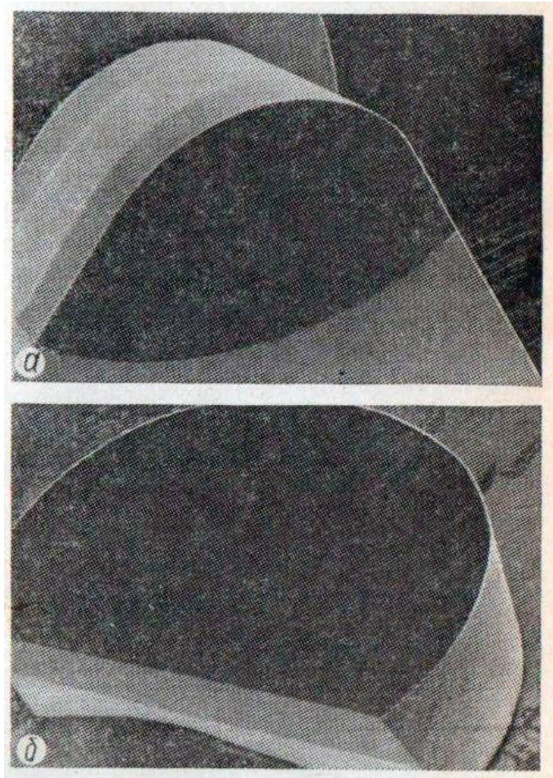
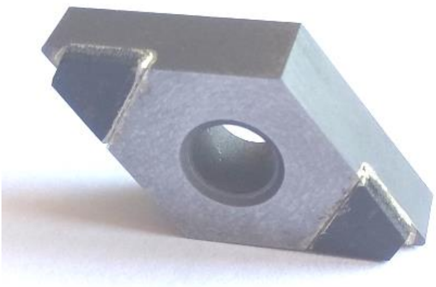
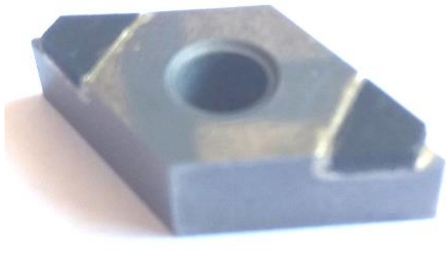


Figure 5: Plates made of super–hard composite materials: a – plate soldered to the body of machining tool, b - segment plate for mechanical hardening



a



b

Figure 6: Machining tools made of superhard polycrystalline material based on boron nitride (BN); a – side view, b – over view.

Figure 5 shows plates made of superhard composite materials: a – plate soldered to the cutter body, b – segment plate for mechanical hardening. In the conditions of «TURON ABRASIVE" LLC, a method is proposed that will install plates on a metal machining tool by soldering in a vacuum furnace for soldering: ZT-JG6SE PCD PCBN.

Figure 6 shows machining tools made of superhard polycrystalline material based on boron nitride.

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

Comparative studies of the mechanical properties of metal-cutting tools for various purposes made of standard powders and mixtures using superhard composite materials were carried out at the production enterprise of «TURON ABRASIVE» LLC and the plates were tested in the conditions of «Jizzakh Automobile Plant» LLC.

4. Conclusions

Based on the research work carried out on the technology of production of superhard composite materials based on diamond and boron nitride for the manufacture of plates of metal machining tools for various purposes made from standard powders and mixtures using superhard composite materials of machine-building enterprises of the Republic of Uzbekistan, the following conclusions are presented:

1. A technology for the production of superhard composite materials has been developed and a new charge composition for the machining part of a metal machining tool has been obtained together with «TURON ABRASIVE» LLC;
2. Modes of pressing mixtures and sintering in a high-pressure press for sintering PCBN and CBN blanks have been developed;
3. Modes of plate machining in a laser cutting machine-ZT-JG6SE have been developed;
4. The modes of sharpening PCBN and CBN plates in the ZT-180 HIGH CNC grinding machine have been developed and proposed:
5. Proposed to install plates in a vacuum soldering oven: ZT-JG6SE PCD PCBN;
6. The results of the work made it possible to increase the service life of the machining tools in the conditions of «Jizzakh Automobile Plant» LLC by 2-3 times.

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