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HIGH-PERFORMANCE DRUM-TYPE ABRASIVE TOOLS EQUIPPED WITH INTERCHANGEABLE CUTTING ELEMENTS WITH SHM

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Abstract. *The processes of synthesis of the working layer of abrasive tools using various methods are considered, their features and disadvantages are noted. The results of the use of laser radiation for sintering composites with superhard materials (SHM) are presented. It is shown for the first time that laser heating of composites containing a metal bond and SHM grains to temperatures of 1600 ºC does not lead to a loss of their strength. The results of the study of the effect of laser radiation with a wavelength of 10.6 and 1.06 µm on SHM grains and a combination of various methods of protecting abrasive grains from thermal effects are presented. It is shown that the time of laser radiation and melting of the bond on SHM grains should not exceed 0.3 s. Data on high-performance drum-type tools equipped with replaceable inserts with SHM are highlighted. The results of mathematical modeling of the processes of forming a layer with SHM, methods for calculating sintering parameters are highlighted, and a set of devices and tools for ensuring the process of manufacturing abrasive diamond inserts for drums is presented.*

Key words*: abrasive tool, bond, laser synthesis, mathematical modeling, superhard materials.*

Introduction. One of the trends in the development of modern machine-building production is the creation of metalworking technological complexes that allow using one or more universal tools to produce parts of various shapes and sizes, while carrying out a full cycle of mechanical processing. Such tools must have high cutting ability and a long period of stability. In addition, to implement optimal cutting kinematics, they must have a rather complex shape (sphere, ellipsoid, hyperboloid, torus, etc.) and a certain geometry of cutting elements. These requirements can be met by tools made of special superhard composite materials.

The main tasks of the technology for manufacturing tools from superhard materials, including diamond, are to obtain the required shape and size, ensure strong fixation of abrasive grains on the working surfaces, and provide them with cutting ability, which must be continuously maintained during operation.

Analyzing the state of diamond tool production technologies in general, it should be noted that they have very low productivity. The demand of the world market significantly exceeds the capabilities of the most modern diamond tool production. In the manufacture of diamond tools, a limited number of bonds are used, containing as a basis only low-melting components with a melting point not exceeding 700˚C [1-8].

This significantly limits the possibilities of its optimal use in processing a wide range of structural materials that differ significantly in hardness, chemical composition and other characteristics. In addition, such bonds do not hold diamond grains firmly enough, which limits cutting performance, tool stability, contributes to an increase in diamond consumption, and processing costs. Existing methods for manufacturing tool composites do not allow controlling the location of diamond grains, especially to create single-row, multi-layer tools.

The most promising and effective method of manufacturing the above-mentioned universal tools is the method of layer-by-layer laser sintering of powder composites.

As shown by the results of research carried out in this direction by specialists of the Department of Laser Technics and Applied technologies of National Technical

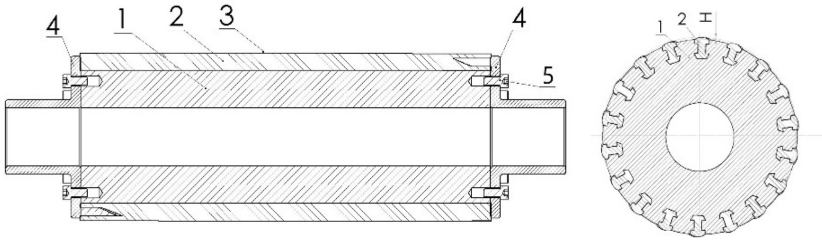
University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” and the Institute of Superhard Materials named after V. M. Bakul, laser radiation allows, due to the high speed of contactless energy input into the material and its precision dosing, to carry out ultrafast heating of local areas of the composite containing a metallic bond (Cu, Fe, Ni) and SHM grains (diamond, cubic boron nitride (CBN)) to temperatures of 1500 - 1600 ºC without loss of their strength and other properties [9]. It has been established that the time of action of laser radiation and melting of the bond on SHM grains should not exceed 0.3 s. With a longer exposure time, their graphitization begins. The high locality of the process allows layer-by-layer formation of single- or multi-row working elements from SHM and, thus, to obtain tools of almost any configuration, to easily control the concentration of composite components, to obtain structures with high dispersion and other physical and mechanical properties. The developed process and manufactured prototypes of diamond disk tools that have passed the tests indicate the feasibility of developing and implementing the development in production.

This study is aimed at expanding the application of laser synthesis processes in the manufacture of cutting elements of high-performance drum-type tools.

Materials and Methods. For mechanical high-performance processing of the external surfaces of large-sized metal and non-metallic products, it is proposed to use a grinding drum in the form of a metal hollow round cylinder with rectangular grooves evenly spaced along its entire length, at a certain distance from each other, at an angle of 5º to its axis. Rectangular metal inserts are tightly installed and fixed in the grooves of a certain width and depth, the length of each of which is 5 mm greater than half the length of the cylinder, on the outer surface of which a layer containing SHM of a given thickness and radius of curvature of its outer surface is applied by laser sintering. Flanges are attached to both ends of the cylinder, on the opposite surfaces of which, corresponding to the protrusions on the ends of the metal inserts, corresponding recesses and holes are made for placing screws that secure the flanges to the housing.

Results and Discussion. The general view of such a drum is presented in Fig. 1a, b. The drum contains several separate elements: directly a metal cylinder with a system of longitudinal grooves 1, rectangular inserts 2 located and fixed in them, on the outer surfaces of which a layer of SHM 3 is applied by laser sintering, which protrudes along the radius from its surface to the working depth of the drum circle H and two flanges 4, fixing and securing the inserts with SHM on the ends of the cylinder with screws 5. One of the main tasks of this work is to determine the conditions for laser sintering of composites containing synthetic diamonds. On the outer surfaces of the inserts, a layer of synthetic diamonds of grades AC 15-H, AC 32-H and grades AC15, AC20 and AC32 with a grain size of 500/400 - 200/160 with a metal bond is applied by laser sintering (AC – synthetic diamond brand).

To determine the conditions for implementing the process of laser liquid-phase synthesis of an abrasive layer from SHM, its mathematical modeling was carried out [10, 11]. In this case, the speed of movement of the workpiece was determined, at which the formation of an abrasive composite from SHM was ensured, the radiation power with a wavelength of 1.06 μm was 1500 W, and the size of the focusing zone varied within 3 mm, 4 mm and 5 mm. The results of the calculations are shown in Fig. 2.



a) b)

1 – body; 2 – inserts; 3 – SHM layer; 4 – flanges; 5 – screws; H – height of the working abrasive layer

Fig. 1. Grinding drum with inserts containing SHM obtained by laser sintering: a) main view b) cross-sectional view

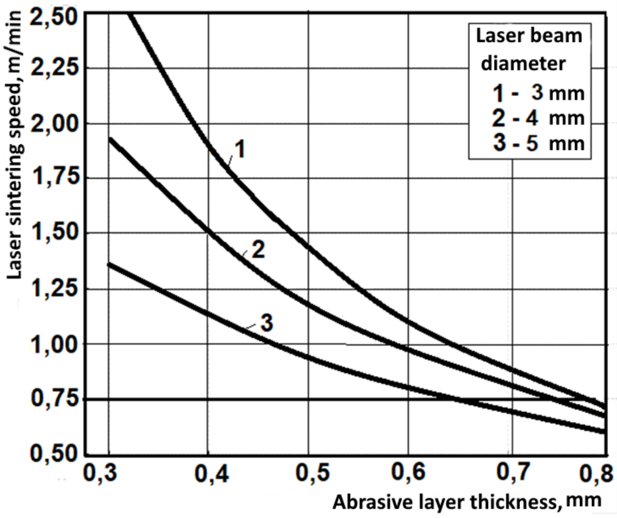


Fig. 2. Movement speed at different thicknesses of the SHM layer and sizes of the focusing zone

Fig. 3 shows a set of devices and tools for ensuring the process of manufacturing inserts from SHM for abrasive drums. The synthesis process is carried out using fiber laser radiation.

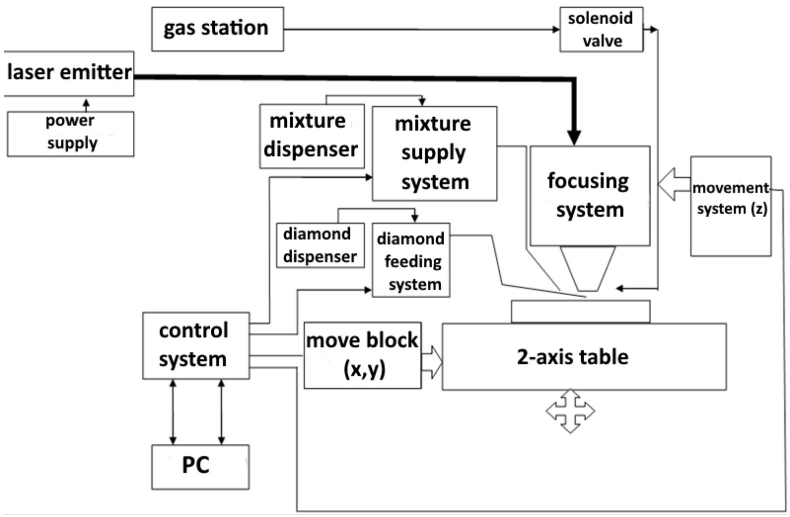


Fig. 3. Block diagram of a laser technological complex for the synthesis of an abrasive layer from SHM

To feed abrasive materials into the synthesis zone, it is necessary to develop a special device that controls the SHM grain feed system, after which they enter the focusing and sintering zone, where the main process of the entire system takes place, namely the synthesis of the abrasive layer on the surface of the insert. In order to control and program the number of SHM grains entering the feed system, a system was modeled, which includes a binder feed system, a laser radiation transportation and focusing system, and a system for accounting and regulated feed of abrasive grains. The sintering process is carried out using fiber or blue lasers by directional heating of the substrate with laser radiation of a mixture of powders to temperatures of 1500-1600°C for 0.2-0.4 seconds, which allows avoiding the phenomenon of graphitization and preserving the initial strength of diamonds. Depending on the selected typesetting plate and other components, the laser radiation power to ensure this process is in the range of 1.0 - 2.5 kW. The diameter of the focusing zone is 0.7-2.0 mm. The scanning amplitude of the laser beam is 7 mm. The scanning frequency is 150-200 Hz. The speed of relative movement of the laser beam and the matrix is (0.2-2.0) m/min. Our device has the ability to adjust the focal distance of the laser beam relative to the typesetting plate. This adjustment is carried out automatically in a mechanical way.

Conclusion. For the first time, a process of laser synthesis of composites based on synthetic SHM s on the working surfaces of tool drum inserts has been developed, which allows to radically (by 20 or more times) increase the productivity of manufacturing such tools, reduce the cost of their manufacture. A new design of a cylindrical tool drum at the level of the invention is proposed, which contains a system of replaceable metal inserts, located with a certain pitch and angle of inclination to its axis (4-5º), on the surfaces of which an abrasive layer of SHM of a certain thickness is applied by laser sintering.

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ВИСОКОПРОДУКТИВНІ АБРАЗИВНІ ІНСТРУМЕНТИ БАРАБАННОГО ТИПУ ОСНАЩЕНІ ЗМІННИМИ РІЖУЧИМИ ЕЛЕМЕНТАМИ З НТМ

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Анотація. *Розглянуто процеси синтезу робочого шару абразивних інструментів з використанням різних способів, відмічені їх особливості, недоліки. Наведені результати застосування лазерного випромінення для спікання композитів з надтвердих матеріалів (НТМ). Вперше показано, що лазерне нагрівання композитів, що містять металеву зв'язку і зерна НТМ до температур 1600 ºС не призводить до втрати їх міцності. Наведено результати дослідження впливу лазерного випромінення з довжиною хвилі 10,6 та 1,06 мкм* *на зерна НТМ та комбінація різних методів захисту зерен абразиву від термічного впливу. Показано, що час дії лазерного випромінення і розплаву зв'язки на зерна НТМ не повинен перевищувати 0,3 с. Висвітлюються дані про високопродуктивні інструменти барабанного типу, оснащених змінними вставками з НТМ. Висвітлюються результати математичного моделювання процесів формування шару з НТМ, методи розрахунку параметрів спікання, представлено комплекс пристроїв та засобів для забезпечення процесу виготовлення абразивних алмазних вставок барабанів.*

***Ключові слова**: абразивний інструмент, зв'язка, лазерний синтез, математичне моделювання, надтверді матеріали*