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IMPROVING THE PERFORMANCE OF DIAMOND GRINDING TOOL BY MODIFYING THE SYNTHETIC DIAMOND SURFACES

Introduction. Machine-building enterprises of Ukraine need a highly efficient diamond grinding tool. For its effective use, it is necessary to use high-quality synthetic diamond powders with improved operational characteristics.

Problem Statement. Among the disadvantages of synthetic diamonds used in grinding tools is their oxidation under high temperature, during high-performance grinding of modern hard-to-machine materials.

Purpose. The purpose of this research is to study the possibilities of improving the operational characteristics of the diamond grinding tool by modifying the surface of synthetic diamond grains.

Material and Methods. The surface of AC6–AC20 diamond powder has been modified by the isothermal method of liquid-phase deposition of heat-resistant oxides (B_2O_3 , Al_2O_3), chlorides ($CaCl_2$, $NaCl$, $MgCl_2$, $FeCl_3$), and their mixes ($B_2O_3 + CaCl_2$, $B_2O_3 + NaCl$) from saturated solutions on the diamond surface.

Results. The basic technology of forming heat-stable wear-resistant coatings on the surface of diamond grinding powder grains from mixes of soluble and insoluble oxygen- (B_2O_3 , TiO_2 , SiO_2 , Al_2O_3 , TiO , CaO , ZnO , CeO_2 , SnO_2), silicate- ($Na_2O(SiO_2)_n$), ($K_2O(SiO_2)_n$) and carbide-containing (SiC , TiC , B_4C) compounds in various combinations. It has been found that the modification allows reducing the costs of diamonds in grinding wheels,

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with the best solution being the modification with B_2O_3 and Al_2O_3 oxides. It has been shown that the modification of the surface of diamond grains with the combination of B_2O_3/Al_2O_3 allows improving the filling of the rough polished surface with material and increasing its holding capacity. It has been established that with an increase in the manufacture cost by as few as 9–11%, the modification of abrasive grains of grinding wheels enhances the wheel wear resistance 2 times.

Conclusions. The use of such purposefully improved diamond grinding powders in the working layer of diamond wheels allows increasing the performance and wear resistance of the diamond grinding tool.

Keywords: diamond grinding tool, synthetic diamond grain surface, diamond oxidation, diamond surface modification, saturated solution, isothermal method, oxides, chlorides, operational characteristics of grinding tool.

Synthetic diamonds and tools based on them are science-intensive products. According to the modern market definition, they can be attributed to the medium or high-tech industry that include aircraft, automobile and instrument engineering, pharmaceuticals, and chemical industry. One of the world centers for diamond business in Ukraine is the Bakul Institute of Superhard Materials of the National Academy of Sciences of Ukraine. The R&D activity of the Institute is aimed at laying scientific foundations for the creation of cutting-edge technologies for processing metals and non-metals with tools made of hard alloys and superhard materials (SHM) and at developing methods and technologies for the use of new tool materials in the basic industries. The industrialized countries have been more and more focusing on SHM, as the most effective for equipping tools, and this has been evidenced by the fact that now the leading industrialized economies (USA, Japan, Germany, England, Italy, France, and China) use about 80% of mined natural and manufactured synthetic diamonds. At the same time, one of the main areas of application of SHM is mechanical processing, in which about 70% of the total SHM is used.

In the previous research published in *Science & Innovation* journal of the National Academy of Sciences of Ukraine [1], we have considered improving the operational characteristics of high-strength synthetic diamonds AS65–AS250 for high-precision diamond ruling tools. In this research, we consider improving the operational characteristics of a diamond grinding tool that uses diamonds of lesser strength. Thus, AS6–AS20 diamond synthetic powders have been widely em-

ployed in diamond grinding tools in the industry for machining products made of hard alloy, ceramics, glass, and other fragile materials. The further development of modern diamond machining technologies is associated with the use of powders with new unique properties, special grain morphology, and increased chemical and thermal resistance in diamond tools. Thus, one of the causes for the increased consumption of diamonds in the operation of the tool, as well as in the manufacture of some types of tools on a metal binder is oxidation of diamonds under high temperature. The development of effective methods for increasing the heat resistance of grinding powders made of superhard materials, including abrasive grinding powders made of synthetic diamond powders, contributes to improving the quality of grinding tools. To increase the heat resistance of diamonds, they are covered with a metal (metalization) or ceramic layer, and alloying additives of certain elements are introduced into the reaction mix used in the synthesis of diamonds. Other coating methods have also been developed to increase the heat resistance of diamonds, such as: glass coating, vacuum ion-plasma sputtering, epitaxial synthesis, magnetron sputtering, and liquid-phase coating method. That is, modification of the surface, or coating, of diamond grains is one of the important factors influencing changes in their properties, increasing retention in the binding working layer of the grinding tool, and changing the properties of the diamond surface. It should be noted that this direction has been intensively developing. Let us further focus on modern developments in the production of various functional coatings on diamonds and the fea-

tures of their influence on the modification of the surface of diamonds.

The technology of thermo-explosive synthesis can be applied to cover diamond [2]. With the use of mixed Cr/Al/B/diamond powder as a raw material, a multi-component composite coating based on CrB-AlN has been formed on the surface of the diamond by the thermo-explosive synthesis method (Fig. 1). The effect of the protective atmosphere (N or Ar), the content of Al in the phase composition, and the microstructure of the binder and coating have been studied. The results have shown that under the protection of Ar, the raw material does not undergo a thermal explosion reaction. The loose and porous bulk structure can be obtained by the thermal explosion reaction under the protection of N. The coating on the diamond surface is mainly composed of

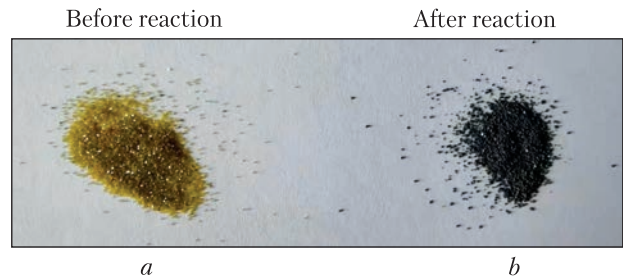


Fig. 1. General view of diamond powders before coating (a) and coated ones (b) [2]

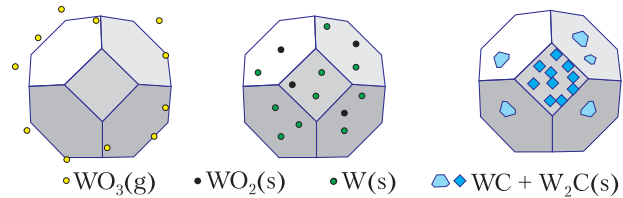


Fig. 2. Changes in the composition of the diamond surface coating as a result of temperature variation [3]

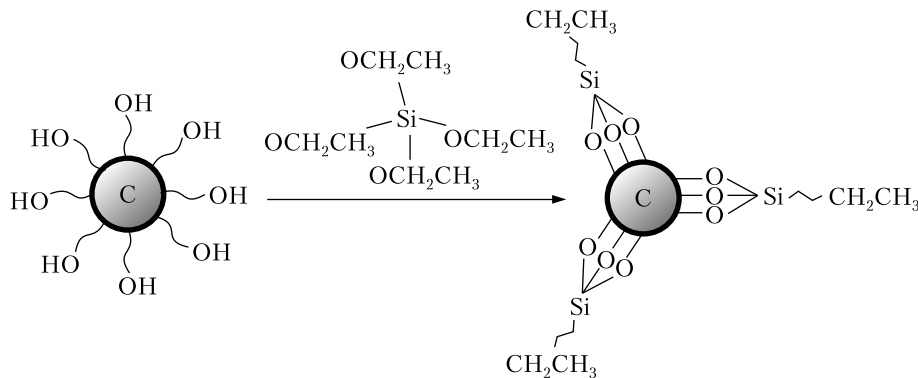


Fig. 3. Scientific principles of diamond surface modification with SiO₂ layer [8]

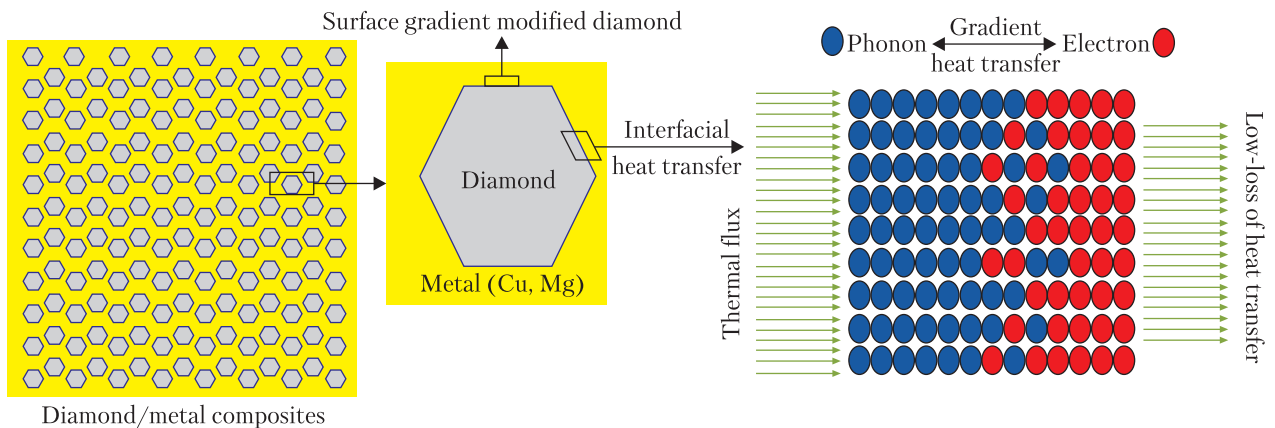


Fig. 4. Scientific principles of metal-based modified diamond surface [9]

CrB and AlN and contains other by-products such as Cr_5Al_8 and Cr_2AlB_2 [2].

Metallic W-containing coatings are applied to the surface of diamond microcrystals by hot pressing, with the use of WO_3 as a metal source [3]. The coatings formed on the diamond surface react with WO_3 powder during hot pressing at elevated temperature. After processing the mix at 850°C for 15 min, WO_2 and $\text{W}_{18}\text{O}_{49}$ are fixed on the diamond surface. After treatment at 950°C (15 min), tungsten is the dominant phase of the coating. Treatment at 1150°C (15 min) leads to the formation of WC and W_2C phases. There is no metallic tungsten in the coating obtained at this temperature (Fig. 2).

In [4], to determine the features of the reaction of diamond with various types of metals and metal oxides, the activation energy of the reaction between diamond and metals, as well as between diamond and metal oxides, has been calculated from the first principles. For the transition metals of the fourth period of the Periodic Table of the Elements, when they react with diamond to form the corresponding metal carbides, the order of increasing activation energy for the metals is as follows: Mn, Fe, V, Ti, Cr, Co, Ni, Zn, and Cu. And when diamond reacts with MnO, FeO, CoO, NiO, and CuO to form metals and CO, the calculated activation energy is, in the descending order, as follows: MnO, FeO, CoO, NiO, and CuO. Thus, it has been established that NiO and CuO are reduced by diamond to Ni and Cu, which indicates a redox reaction between diamond and metal oxides [4].

In [5], diamond particles are coated with thin layers of aluminum oxide (Al_2O_3) by the atomic layer deposition method. As a result, the temperature at which the diamond starts decomposing to CO_2 shifts towards higher temperature (by $\approx 50\text{ K}$) due to the protective effect of Al_2O_3 . The authors of [5] have stated that although the improvement is small enough to be used for high-temperature applications, these results have indicated that this type of coating can be used to protect diamond from oxidation.

Efficient control of interphase electronic states of Al_2O_3 /diamond interfaces has been considered in [6], where calculations have been used to find out the influence of Al_2O_3 and diamond planes on the electronic properties of Al_2O_3 /diamond interfaces. Thus, for the most stable C–Al interface in Al, under conditions of increased Al content, there is achieved strong p-type doping with obvious localization characteristics due to a charge transfer generated at the C–Al interface.

However, the pure diamond coating has a low impact toughness because of its superhardness, which may cause it to peel or break. In [7], a new method of chemical vapor deposition when a diamond coating with CuO particles is applied to a WC/Co substrate has been proposed. A clean diamond coating has been produced for comparison. The indentation tests have shown that the diamond coating with CuO particles has higher adhesion strength and cracking resistance as compared with the pure diamond coating.

In [8], in order to improve the dispersion and adhesion strength in the polishing tool, the surface of diamond abrasives has been modified by applying a layer of SiO_2 by the isothermal hydrolysis method. The results have shown that a thin SiO_2 film is uniformly grafted to the diamond surface (Fig. 3). Polishing films have been produced with the use of unmodified and modified diamonds as an abrasive based on the Sol-Gel technology for polishing SiC substrates. The tests have shown that the diamond abrasives modified with SiO_2 have a higher material removal rate and better polishing quality than the unmodified diamond abrasives. This is caused by an increase in the dispersive ability of abrasive grains and an improvement in the adhesion between the film matrix and abrasives [8].

Research [9] presents an innovative method of molten salts for the reactive preparation of surface-modified diamond particles. Surface-modified composites based on metals (copper or magnesium), reinforced with diamond particles have been obtained by the electrospark plasma sintering method. Diamond particles with a modified sur-

face gradient have been obtained by the method of melting salts (Fig. 4). The results have shown that the thickness of the modified layer on the diamond surface gradually grows as the exposure time increases. The composite materials on a metal base with a modified surface, reinforced with diamond particles, have a high thermal conductivity. With a volume fraction of diamond of 35%, the thermal conductivity of diamond-copper composites reaches $602 \text{ W}/(\text{m} \cdot \text{K})$, while that of diamond-magnesium ones is equal to $286 \text{ W}/(\text{m} \cdot \text{K})$.

In [10], the behavior of pure diamond powders and powders containing 0.2% wt. boron during oxidation has been studied. The boron-doped diamond has shown a significantly higher resistance to oxidation than the pure diamond. The maximum oxidation rate shifts from $773 \text{ }^\circ\text{C}$ for the pure diamond to $1118 \text{ }^\circ\text{C}$ for the boron-doped diamond. The SEM analysis of the surface of partially oxidized diamonds has proven that even such a low boron content (0.2%) is sufficient for the formation of a protective B_2O_3 layer in the areas of active oxidation. According to the authors of [10], it is this layer that is the cause of increased resistance to oxidation.

To some extent, this has been confirmed in [11], where protective coatings made of titanium-boron carbide on diamond particles have been studied. The results have proven that the boron content is important for the adhesion of Ti in the Ti–B–C coating. Such a coating with a boron content of 60 at. % protects the diamond from oxidation for more than 1 h, in the course of to $1000 \text{ }^\circ\text{C}$, in the air. In the case of the Ti–B–C coating with a boron content of 11 at. %, the diamond mass after heating to $1000 \text{ }^\circ\text{C}$ decreases. During annealing of coated diamond in the air, the a priori formed B_2O_3 and TiO_2 protect the diamond from oxidation, acting as oxygen-impermeable layers. In addition, the formation of liquid B_2O_3 allows avoiding the delamination of TiO_2 , as a result of volume expansion during oxidation. Meanwhile, the presence of TiO_2 provides a long-term protection by reducing the evaporation of B_2O_3 [11].

It can be seen from the above that various oxides are used to modify the surface of diamonds:

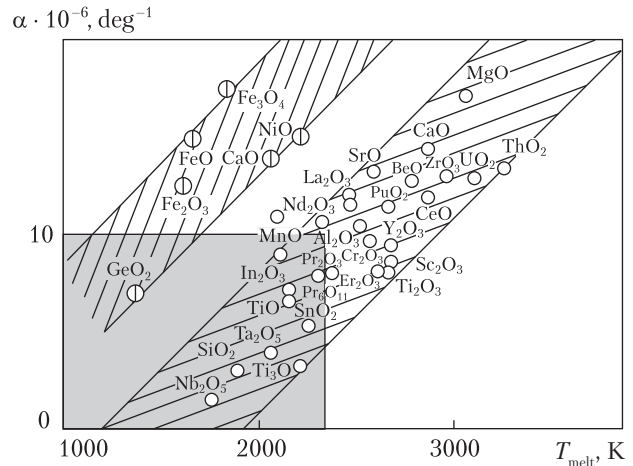


Fig. 5. Correlation of the melting point and the CTE of the oxides [13]

WO_2 , NiO and CuO, Al_2O_3 , SiO_2 and B_2O_3 . At the same time, in [12], the authors have stated that for the cutting processes, oxygen is an important factor in terms of modifying the tribotechnical characteristics of contact surfaces. The oxide layers arising under the action of oxygen or its compounds on contact surfaces significantly reduce friction. The higher the chemical activity of the metal towards oxygen, the greater the effect of friction reduction. Meanwhile, let us return to the influence of oxides on the oxidation of diamonds. In [13], it has been determined which oxides may act so and has been shown that the metal oxides rather than the very metals have a decisive influence on the heat resistance of diamonds. In addition, since diamonds are pressed into the bond of the working layer, it is desirable that such oxides have neither a high coefficient of thermal expansion (CTE) nor a large specific heat capacity. At the same time, it is known [13] that for the metals, the higher the melting point, the lower the CTE. In [13], for the oxides, an inverse relationship has been observed: as the melting temperature (T_{pl}) increases, so does the CTE (α) (Fig. 5). Figure 5 shows that the oxides of metals of the VIII group (iron, cobalt and nickel), as well as germanium occupy a separate area parallel to the main one.

A similar grouping has been also observed in the analysis of the relationship between the CTE and the standard molar heat capacity of oxides [13]. The analysis of the relationship between the density and the heat capacity has shown that the standard heat capacity goes up slightly as the density of oxides increases. A significant increase has been observed for the oxides with the composition of Me_2O_3 . In general, the above-described grouping by the oxide metal valence has been reported. Therefore, oxides have many characteristic features, the analysis of which can be useful, for example, for explaining the behavior of ceramics when heated or for choosing oxides to modify the surface of grains with oxides. Given the experimental data obtained by the authors [12] on the introduction of oxides into the contact zone of the grinding wheel and the machined product, as well as the correlation dependences obtained above, it has been determined that for the modification of the grains of grinding powders, the use of oxides with a CTE higher than $10 \cdot 10^{-6}$, deg^{-1} is impractical. Other limitations, according to the authors, are limitations on the melting temperature of such oxides – at most, 2300 K, see Fig. 5, on the specific molar heat capacity (at most, 80 J/(mol · K) and on the density of oxides – at, most $5 \cdot 10^3$ kg/m³ [13].

Given the above limitations, the oxides that can be used in the modification of the surface of diamond grains with heat-resistant oxides should include a significant part of the oxides of the MeO_2 group (TiO_2 , SiO_2 , GeO_2 , SnO_2), while the oxides of Me_2O_3 (N_2O_3 , B_2O_3 , Al_2O_3) and MeO (TiO , BaO , BeO , CaO) groups may be lesser employed [13].

Considering the relevance of the problem outlined above, it has been considered appropriate to conduct research on the creation of a technology for modifying the surface of diamond grains with the above-mentioned oxides or their mixes, the use of which would raise the efficiency of the grinding tool, therefore the purpose of this research is to develop the process of forming heat-stable wear-resistant coatings on the surface of grains of abra-

sive grinding powders with the use of mixes of soluble and insoluble oxygen-, silicate- and carbide-containing activated components.

Averaged samples of grinding powders from synthetic diamonds: AC6 125/100 and AC15 250/200 as raw material have been selected for the research. The surface of powder grains has been modified by the isothermal method of liquid-phase application from saturated solutions of heat-resistant oxides (B_2O_3), chlorides ($CaCl_2$, $NaCl$, $MgCl_2$, $FeCl_3$), and their mixes ($B_2O_3 + CaCl_2$, $B_2O_3 + NaCl$). The structural and morphological characteristics of the external structure and the quantitative elemental composition of the modified powders have been determined with the use of a ZEISS EVO 50XVP scanning electron microscope (SEM) equipped with an INCA ENERGY 450 energy dispersive X-ray spectrum analyzer.

The modification of the surface of powder materials by the method of liquid-phase application is the process of deposition of a modifier substance that is released (crystallized) from a solution in the form of crystals or films, on the surface of a solid body (in our case, diamond grinding powder). The modifier is fixed on the grains of such a powder due to the process of physical adsorption, the phenomenon of absorption of gases, salts, or other substances from solutions by some solid bodies. The active centers that exist on the surface of the synthetic diamond grains are the primary centers of fixation of the modifier. In our physical adsorption (modification) process, the adsorbent is synthetic diamond grinding powder, the adsorbate is the deposited layer of the modifier substance ($B_2O_3/NaCl/CaCl_2/...$), and the substance to be adsorbed (adsorptive) is the saturated solution of the modifier substance. In the liquid-phase method of the formation of deposited layer from a solution of heat-resistant compounds (for example, B_2O_3 , $CaCl_2$, $MgCl_2$, $FeCl_3$, etc.), when the substance is deposited on the surface of the grains of the powder material, the substance gets crystallized. This occurs in the case of a saturated solution and is positive, as it helps to

achieve a sufficient thickness of the deposited layer. As our research has shown, even with a short duration of the modification process, the size of the formed crystals is significantly smaller (by one or two orders of magnitude) as compared with the size of the diamond grains.

We have developed the basic technology for liquid-phase formation on grains of diamond grinding powders of combined heat-stable wear-resistant coatings, i.e. the modification of the surface of diamond grains. The composition of the coating includes oxygen- (B_2O_3 , TiO_2 , SiO_2 , Al_2O_3 , TiO , CaO , ZnO , CeO_2 , SnO_2), silicate- ($Na_2O(SiO_2)_n$, ($K_2O(SiO_2)_n$), and carbide-containing compounds (SiC , TiC , B_4C) in various combinations. Initially, the insoluble components are activated by the mechanochemical method. First, a saturated aqueous solution of boric anhydride (B_2O_3) is prepared. 0.3–0.5 g of activated insoluble oxide powder (TiO_2 , SiO_2 , Al_2O_3 , TiO , CaO , ZnO , CeO_2 , SnO_2) and/or insoluble carbide (SiC , TiC , B_4C) is added to 10–15 ml of the solution. The diamond powder (the weight of the powder sample for the experiment is 25–30 ct) to be coated is mixed with 10–15 ml of a saturated solution of the modifier substance (boric anhydride and insoluble oxide and/or carbide) with the use of a magnetic stirrer for 10 min under normal conditions. The excess solution is poured off, with the remaining mix filtered. The precipitate on the filter is added to the bulk of the modified powder. Finally, we dry the obtained wet powder, while stirring, at a temperature of 120 °C until get a dry, homogeneous state.

Having applied the coating, we determine the relative amount of the modifier substance by the gravimetric method, as well as the change in the heat resistance of the coated (modified) powders. Both the original and the modified samples are treated with heat in the air in a tube furnace at a temperature of 900 °C for 1 h. The samples are weighed before and after heating, with the heat resistance coefficient K_{ts} determined on the basis of the weighing results. So, K_{ts} for the original AS6 125/100 abrasive powder is 0.55, while, for the same abrasive

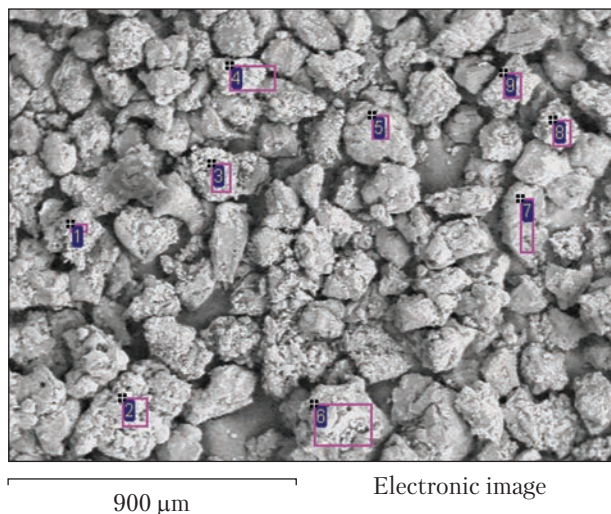


Fig. 6. The areas of coverage, which are subject to the element analysis on the surface of the grains three times modified with B_2O_3

powder modified with a mix of soluble and insoluble oxides $B_2O_3 + Al_2O_3$ (or SiO_2 , TiO_2 , SnO_2 , CeO_2 ; CaO , ZnO), it ranges 0.95–0.97.

The average coverage of diamond grains, for example, by boron oxide (B_2O_3) is 5.64% (the B_2O_3 density is 2.55 g/cm³, the diamond density is 3.56 g/cm³).

Figure 6 shows a sample of AS6 125/100 diamond grinding powder that is three times modified with B_2O_3 oxide and the regions in which the

Table 1. Quantitative Element Composition (% wt.) of the Studied Diamond Grains

Spectrum	Elements, % wt.		
	B	C	O
1	10.05	28.63	61.32
2	12.53	19.69	67.79
3	4.85	41.01	54.14
4	8.87	28.78	62.35
5	0.00	34.53	65.47
6	7.16	37.88	54.96
7	5.17	72.26	22.58
8	9.44	41.60	48.97
9	8.52	26.96	64.52

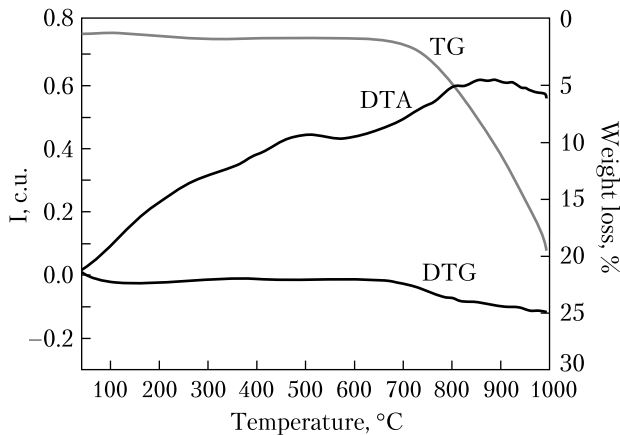


Fig. 7. Thermogram of the sample of synthetic diamond grinding powder AS6 125/100 (original, non-machined)

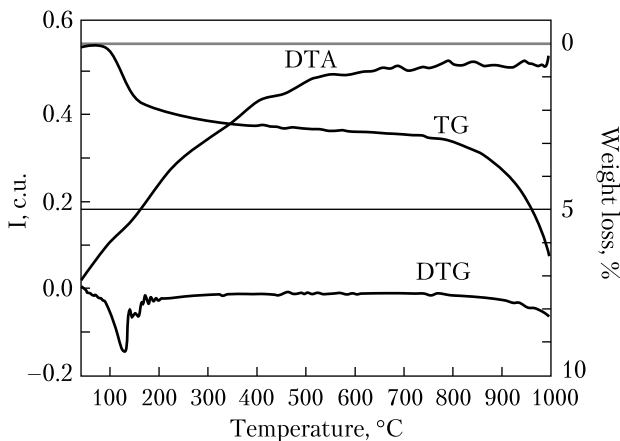


Fig. 8. Thermogram of the sample of AS6 125/100 synthetic diamond grinding powder modified with B₂O₃

elemental composition of the grain surfaces of the sample is determined by the method of local X-ray spectral (LXRS) analysis.

The results of the quantitative LXRS analysis of the sample (three times modified with B₂O₃) (Table 1) have shown that the content of carbon (diamond) ranges from 72.26 to 19.69%, that of boron varies from 0.0 to 12.53%, and that of oxygen ranges from 22.58 to 67.79%.

The indicated diamond grinding powders have been examined by the method of differential thermal analysis on the Q-1500 D derivatograph. Figures 7 and 8 present the results of thermogravimetric, differential-thermogravimetric, and differential thermal analysis of AS6 125/100 synthetic diamond grinding powder samples: the original sample and the sample with the diamond grain surface modified with B₂O₃.

The weight of the samples is 150 mg, the heating rate is 10 °/min. The weight loss after complete cooling of the furnace: 26.3%, for the original sample, and 7.5%, for the modified sample, i.e. the weight loss of the modified sample is 3.5 times less as compared with the original one. Thus, based on the analysis of the research results, it is possible to state that the modification of the diamond surface with oxides increases the heat resistance of synthetic diamond grinding powders.

Further, we have investigated the operational characteristics of diamond wheels with grinding

Table 2. Operational Indicators of Diamond Grinding Wheels on Polymer Bond B2-08 with a Relative Concentration of Grains of 100%, with Various Options for Surface Modification of AS6 125/100 Diamond Grains for Grinding Hard Alloy T15K6 with a Productivity of 400 mm³/min

Options for modifying the surface of diamond grains in the working layer of diamond wheels 12A2-45° 125 × 5 × 3 × 32	Relative consumption of diamonds in the wheel during grinding, q, mg/g	Roughness of the machined surface by parameter Ra, μm
Modification with B ₂ O ₃ (50% of grains) and with Al ₂ O ₃ (50% of grains)	17	0.43
Modification with B ₂ O ₃	32	0.49
W/o grain surface modification	37	0.52
Modification with (B ₂ O ₃ + CaCl ₂) mix	43	0.40
Modification with NaCl	46	0.44

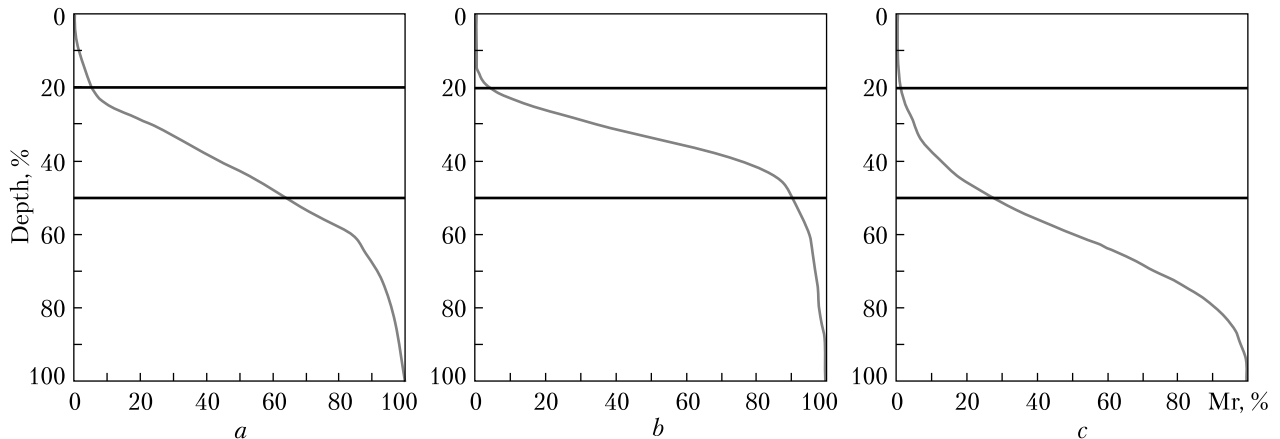


Fig. 9. Dependence of the relative reference length of the profile of the surface machined by a wheel without diamond grain surface modification (*a*), by a wheel with modification of the grain surface by a combination of B_2O_3/Al_2O_3 (*b*), and by a wheel with modification of the grain surface with NaCl (*c*), during grinding of a hard alloy with a productivity of $400 \text{ mm}^3/\text{min}$

powders of AS6 synthetic diamond with the above-mentioned surface modifications. For machining, we have elected hard-workable tungsten-titanium-cobalt T15K6 hard alloy with sample dimensions of $63 \times 15 \times 7 \text{ mm}$. The grinding conditions are as follows: the wheel rotation speed is 18 m/s , the transverse feed is $0.05 \text{ mm/revolution}$, the longitudinal feed is 0.57 m/min (at a productivity of $200 \text{ mm}^3/\text{min}$) and 1.14 m/min (at a productivity of $400 \text{ mm}^3/\text{min}$). The wear resistance of the grinding tool is evaluated according to the indicator of relative consumption of diamonds (q) and the roughness of the machined surface according to the indicator (Ra). The test results are shown in Table 2.

The Table data show that the modification allows reducing the consumption of diamonds in the grinding wheels, with the modification with B_2O_3 and Al_2O_3 oxides being the best option. At the same time, the modification of the diamond grain surface with chlorides worsens the wear resistance of the diamond tool. The difference in the diamond wheel wear for the option without modification and that with surface modification with B_2O_3/Al_2O_3 is 2.18. That is, the modification of the surface of diamond grains with a combination of B_2O_3/Al_2O_3 guarantees a double increase in the wear resistance of diamond grinding wheels.

In general, even despite a certain increase in the cost of diamond grains by approximately 9–11%, due to the introduction of an additional operation – the modification of their surface – the modification of diamond grains by the B_2O_3/Al_2O_3 combination leads to, at least, a double increase in the wear resistance of grinding wheels.

Now, let us consider the roughness of the machined surface (see Table). It can be seen that in all cases of the modification, the roughness (Ra parameter) decreases. The modifiers that have the effect of reducing the Ra parameter can be arranged in the Ra ascending order as:



In addition, we have found that, if necessary, changing the surface modifier of diamond grains, it is possible to influence the holding capacity of the rough surface obtained during the grinding (Fig. 9).

Figure 9 shows that the modification of the diamond grain surface with combination of B_2O_3/Al_2O_3 allows increasing the filling of the rough surface with material (the larger the surface area under the curve of the relative reference length of the profile, the higher the filling) and enhancing its holding capacity. The modification of the diamond grain surface with NaCl leads to a significant decrease in the density of the rough layer

and the holding capacity of the surface. The latter can be used in the case when it is necessary to quickly refine the surface of a part.

CONCLUSIONS

1. The analysis of literature data has proven that various oxides have been used to modify the surface of diamond grains: WO_2 , NiO and CuO , Al_2O_3 , SiO_2 , and B_2O_3 , which mainly contribute to the protection of diamond grains from oxidation, both in the manufacture of grinding wheels and in the process of diamond grinding.

2. The basic technology for the formation of combined liquid-phase thermostable wear-resistant coatings on the grains of diamond grinding powders, i.e., the modification of the diamond grain surface has been developed. The composition of the coating includes oxygen- (B_2O_3 , TiO_2 , SiO_2 , Al_2O_3 , TiO , CaO , ZnO , CeO_2 , and SnO_2), silicate- ($\text{Na}_2\text{O}(\text{SiO}_2)_n$, $\text{K}_2\text{O}(\text{SiO}_2)_n$), and carbide-containing compounds (SiC , TiC , B_4C) in various combinations. The insoluble components are pre-activated by the mechanochemical method.

3. Heat treatment of both original and modified samples is carried out in the air environment, in a tube furnace at a temperature of 900°C for 1 h. The samples are weighed before and after heating, with the heat resistance coefficient K_{ts} determined based on the weighing results. So, for the original AS6 125/100 abrasive powder, the K_{ts} value is equal to 0.55, while for the same abrasive powder modified with a mix of soluble and insoluble oxides $\text{B}_2\text{O}_3 + \text{Al}_2\text{O}_3$ (or: SiO_2 , TiO_2 , SnO_2 , CeO_2 ; CaO , and ZnO), K_{ts} ranges within 0.95–0.97.

4. It has been established that the modification allows reducing the consumption of diamonds in the grinding wheels, with the modification by B_2O_3 and Al_2O_3 oxides being the best option. At the same time, the modification of the diamond grain surface with chlorides worsens the wear re-

sistance of the diamond tool. The ratio of the diamond wheel wear without modification to that with surface modification by $\text{B}_2\text{O}_3/\text{Al}_2\text{O}_3$ is 2.18. That is, the modification of the surface of diamond grains with a combination of $\text{B}_2\text{O}_3/\text{Al}_2\text{O}_3$ guarantees a double increase in the wear resistance of diamond grinding wheels.

5. Although the modification of the surface of diamond grains leads to a slight increase (by 9–11%) in the cost of diamond grains due to the introduction of an additional operation, but this increase is compensated by a significant (at least, doubles) increase in the wear resistance of expensive diamond wheels.

6. It has been established that in all cases of the modification, the roughness in terms of the Ra parameter decreases. The modifiers that have the effect of reducing the Ra parameter can be arranged in the Ra ascending order as follows: $\text{B}_2\text{O}_3/\text{CaCl}_2 - \text{B}_2\text{O}_3/\text{Al}_2\text{O}_3 - \text{NaCl} - \text{B}_2\text{O}_3$.

7. The modification of the surface of diamond grains with combination of $\text{B}_2\text{O}_3/\text{Al}_2\text{O}_3$ allows increasing the filling of the rough surface with material (the larger the surface area under the curve of the relative reference length of the profile, the higher the filling) and enhancing its holding capacity. The modification of the diamond grain surface with NaCl leads to a significant decrease in the density of the rough layer and the holding capacity of the surface. The latter can be used in the case when it is necessary to quickly refine the surface of a part.

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Conflict of Interest. The authors declare no conflict of interest.

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ПОЛІПШЕННЯ ЕКСПЛУАТАЦІЙНИХ ХАРАКТЕРИСТИК АЛМАЗНОГО ШЛІФУВАЛЬНОГО ІНСТРУМЕНТУ МОДИФІКАЦІЄЮ ПОВЕРХНІ ЗЕРЕН СИНТЕТИЧНИХ АЛМАЗІВ

Вступ. Підприємствам машинобудування України потрібен високоефективний алмазний шліфувальний інструмент. Для його ефективного використання необхідним є застосування в ньому порошоків синтетичного алмаза високої якості з поліпшеними експлуатаційними характеристиками.

Проблематика. У шліфувальному інструменті застосовують синтетичні алмази, одним з недоліків яких є схильність до окислення за умов високих температур, які можуть виникати при високопродуктивному шліфуванні сучасних важкооброблюваних матеріалів.

Мета. Дослідження можливостей поліпшення експлуатаційних характеристик алмазного шліфувального інструменту спрямованою модифікацією поверхні зерен синтетичних алмазів.

Матеріали й методи. Модифікування поверхні алмазних порошоків марок АС6—АС20 здійснювали ізотермічним методом рідинно-фазного нанесення з насичених розчинів на поверхню алмазів як термостійких оксидів (B_2O_3 , Al_2O_3), хлоридів ($CaCl_2$, $NaCl$, $MgCl_2$, $FeCl_3$), так і їхніх сумішей ($B_2O_3 + CaCl_2$, $B_2O_3 + NaCl$).

Результати. Розроблено базову технологію формування термостабільних зносостійких покриттів на поверхні зерен алмазних шліфпорошків з сумішей розчинних та нерозчинних кисне- (B_2O_3 , TiO_2 , SiO_2 , Al_2O_3 , TiO , CaO , ZnO , CeO_2 , SnO_2), силікато- ($Na_2O(SiO_2)_n$), ($K_2O(SiO_2)_n$) та карбидовмісних (SiC , TiC , B_4C) сполук у різних поєднаннях. Встановлено, що модифікування дозволяє знизити витрати алмазів у кругах при шліфуванні, а найефективнішим є модифікування оксидами B_2O_3 та Al_2O_3 . Показано, що модифікація поверхні алмазних зерен комбінацією B_2O_3/Al_2O_3 дозволяє підвищити заповненість матеріалом шорсткої шліфованої поверхні та збільшити її тримальну здатність. Встановлено, що при підвищенні собівартості виготовлення покриття на 9—11 % шляхом модифікування зерен абразиву шліфувальних кругів їхня зносостійкість підвищується вдвічі.

Висновки. Застосування в робочому шарі алмазних кругів таких спрямованих поліпшених алмазних шліфпорошків дозволяє підвищити експлуатаційні характеристики алмазного шліфувального інструменту та збільшити його зносостійкість.

Ключові слова: алмазний шліфувальний інструмент, поверхня зерен синтетичного алмаза, окислення алмаза, модифікування поверхні алмаза, насичений розчин, ізотермічний метод, оксиди, хлориди, експлуатаційні характеристики шліфувального інструменту.