https://doi.org/10.15407/scine17.06.072

LAVRINENKO, V. I.[1] (https://orcid.org/0000-0003-2098-7992),
ILNITSKAYA, G. D.[1] (https://orcid.org/0000-0001-5124-1646),
SHEIKO, M. M.[1] (https://orcid.org/0000-0001-7490-7674),
DOBROSKOK, V. L.[2] (https://orcid.org/0000-0003-4090-6272),
OSROVERH, Ye. V.[2] (https://orcid.org/0000-0002-8926-1324),
and SOLOD, V. Yu.[3] (https://orcid.org/0000-0002-7516-9535)
[1] Bakul Institute for Superhard Materials, the NAS of Ukraine,
2, Avtozavodska St., Kyiv, 04074, Ukraine,
+380 44 468 8632, secretar@ism.kiev.ua
[2] National Technical University Kharkiv Polytechnic Institute, Kharkiv, Ukraine,
2, Kurpichova St., Kharkiv, 61000, Ukraine,
+380 57 700 1564, omsroot@kpi.kharkov.ua
[3] Dniprovsk State Technical University,
Kamianske, Ukraine
2, Dniprobudivska St., Kamianske, Dipropetrovsk Region, 51918, Ukraine,
+380 569 56 0667, science@dstu.dp.ua

IMPROVING THE PERFORMANCE CHARACTERISTICS OF SYNTHETIC DIAMONDS FOR HIGH-PRECISION DIAMOND DRESSING TOOL

Introduction. *Ukrainian machine-building enterprises, especially engine- and aircraft-building, need a precision diamond dressing tool. For its effective operation, it is necessary to use high-quality synthetic diamond powders with controllable strength and heat resistance, as well as geometric grain size.*

Problem Statement. *Synthetic diamonds are synthesized in different growth systems, so they differ significantly in the presence of intracrystalline impurities and inclusions, and hence have different properties.*

Purpose. *To study the possibilities of improving the physical and mechanical properties of diamond grinding powders by effective sorting out by grain surface defects.*

Materials and Methods. *The physical and mechanical properties of AS65—AS250 diamond powders: strength under static compression, coefficient of uniformity in terms of strength, heat resistance and specific magnetic susceptibility have been determined. The elemental composition of impurities and inclusions in powders has been established by the X-ray fluorescence integrated analysis, with the use of BS-340 scanning electron microscope and Link-860 energy-dispersive X-ray spectrum analyzer.*

Results. *It has been shown that the separation of diamonds in a magnetic field of different intensity contributes to the production of grinding powders that differ in the content of impurities and inclusions and therefore, different physical and mechanical properties. In general, the fewer impurities and inclusions the diamond crystals*

Citation: Lavrinenko V. I., Ilnitskaya G. D., Sheiko M. M., Dobroskok V. L., Osroverh Ye. V., and Solod V. Yu. Improving the Performance Characteristics of Synthetic Diamonds for High-Precision Diamond Dressing Tool. *Sci. innov.* 2021. V. 17, no. 6. P. 72—82. https://doi.org/10.15407/scine17.06.072

of all systems contain, the higher is their strength. To achieve this, the diamond grinding powders have been sorted out in a special way. For this purpose, the method of adhesive-magnetic sorting of diamond grinding powders has been improved: the surface treatment of grinding powder grains is provided by depositing electrically conductive fine particles and their adhesive fixing on the surface of diamond grains to obtain the required electrical properties.

Conclusion. *The use of the improved diamond grinding powders in the tool allows increasing the efficiency of the diamond dressing tool.*

Keywords: precision dressing tool, synthetic diamond grinding powders, synthetic diamond surface defect, growth synthesis systems, sorting, and improvement of synthetic diamond performance.

The plunge-cut grinding operations that provide the greatest labor productivity and a high accuracy and stability of quality of the machined products have been getting increasingly widespread in serial and large-scale production of parts for world mechanical engineering. In this case, the grinding process is more than a mere finishing operation, therefore, the role of diamond guide rollers designed to form the grinding wheel profile with high cutting properties of its working surface, for minimal time. Recently, joint efforts of researchers and manufacturers of global corporations have resulted in practical developments of various dressing and truing tools that differ both in terms of design and technology of their manufacture. The use of synthetic diamonds is widely used in the production of dressing tools. In some cases, the simplification of design and technology for manufacturing of diamond dressing rollers has allowed a sharp reduction of their cost. Recently diamond rollers have been widely used not only in mass and large-scale production, but even in small-scale one. This is especially true for the dressing tools made of synthetic diamonds. Having only 3—5 times less durability, but providing high quality of machined parts, the diamond dressing rollers made of synthetic diamonds have been widely used in many fields of mechanical engineering, since they are ten times cheaper as compared with a similar tool made of natural diamonds. Moreover, the availability of a sufficient raw material of synthetic diamonds allows maximum simplification of the technology for manufacturing diamond dressing rollers, with the use of the mold technology (multilayer diamond dressing rollers) or the electroplating methods (single-layer diamond dressing rollers).

In many branches of mechanical engineering, such as, roller-bearing, tool and optical-mechanical production, the share of the use of high-precision tools in manufacturing the products reaches 50%. Meanwhile, the cost of such a precision tool, especially diamond one, reaches USD 1,000 and the problem of extension of its service life is extremely important. However, the above tool is extremely profitable for the production of Ukraine, because the cost of diamonds in the above tool reaches USD 200 per 1 carat, while, for example, in a standard grinding tool, the cost of diamonds ranges from USD 0.5 to USD 1.0 US per 1 carat. Therefore, elaborating a technology for creating new dressing tools with an extended service life for truing highly abrasive composites is very important and relevant.

Ukrainian machine-building enterprises, especially the engine-building ones, aggregate and hydro-aggregate plants, aircraft-building corporations need precision dressing tools. In Ukraine's market, there are imported dressing tools manufactured by *CORUS* (Switzerland), *Schaundt and Reishauer* (Germany), *Terek Diamond Plant* (Russia), and *Tyrolit* (Austria). These tools are expensive, and to buy them the enterprises need to have foreign currency. At the same time, in order to meet the needs of Ukrainian enterprises in such tools, as well as to enter the foreign market, the National Academy of Sciences of Ukraine (Bakul Institute of Superhard Materials in cooperation with the universities of the Ministry of Education and Science of Ukraine) has been developing and manufacturing effective dressing tools, as shown on the website of the NAS of Ukraine in the reference publication *the Promising R&Ds of the NAS of Ukraine* since 2017. Meanwhile, over time, there is a need for innovative improvement of these tools, which is the purpose of this research.

The existing negative trends in the development of Ukraine's economy and the projected long period of its renewal have forced Ukrainian manufacturers to look for opportunities to sell their products abroad. The EU market as the world largest production site is promising for this goal. It should be noted that when promoting products on this market, Ukrainian manufacturers face a number of problems, namely: the products are not certified according to European standards, the European protectionist approach "buy your own," customs and language barriers, restrictions on payment instruments, etc. The absence of an export risk insurance system in Ukraine does not allow for the shipment of products with deferred payment under the guarantee of an insurance company, which is practiced in all Eurozone countries. However, the main obstacle is Ukraine's low rating in terms of business startups, which scares away potential counterparties and virtually nullifies attempts to establish direct cooperation with large European consumers of Ukrainian products. Practically, the only way for the Ukrainian manufacturers to find partners, mainly with Ukrainian "roots" who can help to promote the products on the European market. At the same time, Bakul ISM of the NAS of Ukraine can compete in the manufacture and supply to the EU market of unique, science-intensive, high-tech tools made of superhard materials, which production is not very popular among large manufacturers.

Examples of such products are precision diamond rollers for machining complex products: turbine blade locks, bearing parts, hydraulic pumps, piston rings, car engine valves, etc., the manufacturing technology for which is available for a limited number of countries, as well as new configurations of large diamond grinding wheel on polymer bonds: 1A1 500×60×6×203, 1A1 600×50×10×305, and 1A1 750×50×10×305. The production of such tools does not allow for the automation of technological operations; it is very individual and gives the manufacturer a chance to occupy its niche in this market segment.

The hardest bonds are used to make the dressing rollers, the most common of which is nickel-galvanic (Vickers hardness is from 2 to 4 GPa). The requirements for diamond powder are especially strong (AC100—AC250). The grain size of diamonds for the dressing tool shall range from 250/200 to 1000/800. The finer powders are used for the manufacture of small profiles, while the coarser powders are suitable for flat profiles without sharp edges. To achieve a high accuracy in the range of 3—5 μm, the diamond powder is additionally sieved in order to obtain the content of the fractions adjacent to the main grain size, which does not exceed 5% beyond the upper and lower limits.

At the same time, at the present stage the development of advanced technologies for machining of machine parts with the use of dressing rollers necessitates the use of high-quality diamond powders with controlled characteristics of strength and heat resistance, as well as geometric grain sizes. The strength of diamonds for precision dressing rollers is necessary, but not sufficient characteristic: the main indicator of the quality of synthetic diamonds used in the dressing tool is the content of impurities and inclusions in them, and it depends on the manufacturer's synthesis conditions. Our research has shown that the predominant elements in the composition of intracrystalline impurities and inclusions in diamond crystals are the metals of the carbon solvent alloy, which give the diamond crystals magnetic properties (Table 1). Grinding powders of diamonds with a grain size of 400/315 of different grades synthesized in Ni–Mn–C, Fe–Co–C, and Fe–Ni–C systems have been studied.

While studying grinding powders of synthetic diamonds with a grain size of 400/315 of different grades, which are synthesized in different growth systems, the magnetic susceptibility of each powder and the elemental composition of inclusions and impurities by means of X-ray fluorescence analysis have been determined. The sum of all identified elements corresponds to the total content of inclusions, and the sum of the elements of

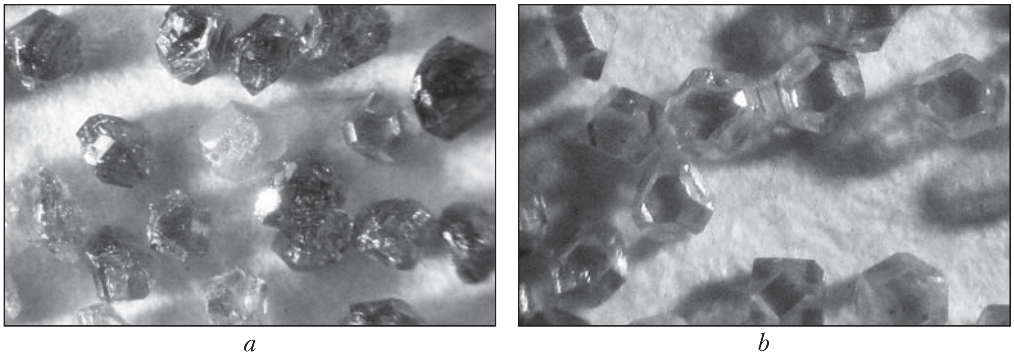


Fig. 1. General view of diamonds of the same grade AC100 630/500, but having different content of impurities and inclusions and, therefore, different colors: *a* — manufacturer 3 (see Table 2); *b* — manufacturer 1 (see Table 2).

the solvent alloy makes it possible to estimate their content in the diamond powder. In general, high-strength heat-resistant synthetic diamond grinding powders synthesized in Fe–Ni–C system contain fewer intracrystalline impurities and inclusions and have a high strength and heat resistance. In addition, the further analysis has shown that grinding powders of synthetic diamond of different grades, which are synthesized in different growth systems Ni–Mn–C, Fe–Co–C, and Fe–Ni–C, differ from each other in the magnetic properties. Therefore, the content of intracrystalline impurities and inclusions in diamond crystals, which is well visible from variation of diamond color, may be estimated based on changes in the magnetic properties, by measuring the specific magnetic susceptibility.

This is what we observe, when comparing, the general appearance of, for example, AC100 630/500 diamonds from different manufacturers (Fig. 1) conventionally marked with 1 and 3 (Table 2).

The diamond grinding powders of grades AC100 and AC200, with grain sizes 630/500, 500/400, 315/250, and 250/200 of the three dif-

Table 1. **Elemental Composition of Intracrystalline Impurities and Inclusions in Diamond Grinding Powders with a Grain Size of 400/315 of Different Growth Systems: Ni–Mn–C, Fe–Co–C, and Fe–Ni–C**

Grade	Elemental composition, % wt.										Total content of inclusions, % wt.
	Si	Ca	Ti	Cr	Fe	Co	Ni	Mn	Cu	Zn	
Ni–Mn–C											
AC125	0.040	0.003	0.003	0.014	0	0.006	0.541	0.471	0.021	0.009	1.108
AC80	0.046	0.005	0.006	0.018	0.017	0.011	1.136	0.865	0.024	0.010	2.138
AC50	0.051	0.007	0.009	0.0020	0.037	0.017	1.390	1.00	0.031	0.014	3.017
Fe–Co–C											
AC160	–	0.002	–	0.012	0.254	0.195	0.011	–	0.005	0.002	0.481
AC100	–	0.005	0.006	0.054	0.297	0.239	0.028	–	0.006	0.002	0.637
AC80	0.010	0.013	0.016	0.084	0.398	0.341	0.039	–	0.008	0.003	0.912
AC65	0.011	0.015	0.029	0.123	0.683	0.785	0.084	–	0.010	0.005	1.745
AC50	0.011	0.019	0.035	0.311	0.736	0.825	0.107	–	0.011	0.007	2.062
Fe–Ni–C											
AC250	–	0.015	–	–	0.161	0.016	0.114	0.003	0.022	–	0.331
AC200	–	0.026	–	–	0.212	0.031	0.124	0.007	0.039	–	0.439
AC160	–	0.040	0.016	0.060	0.222	0.058	0.139	0.010	0.058	–	0.617

ferent manufacturers conventionally designated by us as 1—3 have been studied. The changes in the magnetic and strength properties of the diamonds have been evaluated by the methods developed in Bakul ISM of the NAS of Ukraine. The results for the physical and mechanical properties of grades AC100 and AC200, grain sizes 630/500, 500/400, 315/250, and 250/200 are given in Tables 2 and 3.

As one can see from the above Tables, the studied powders have high strength characteristics and different magnetic properties. As we have already mentioned above, the physical and mechanical properties of synthetic diamond grinding powders used for dressing rollers have a great influence on the efficiency of the tool operation.

Table 2. **Physico-Mechanical Properties of AC100 Diamonds from Different Manufacturers**

Conditional name of manufacturer groups	Strength of diamonds under static compression, *P*, N	Specific magnetic susceptibility, $\chi \cdot 10^{-8}$, m^3/kg
	Grain size 630/500	
1	230	927.0
2	255	69.0
3	278	5.9
	Grain size 315/250	
1	143	16.4
2	131	19.0
3	158	–0.25
	Grain size 250/200	
1	125	0.64
2	118	7.9
3	137	–0.5

Table 3. **Physico-Mechanical Properties of AC200 Diamonds from Different Manufacturers**

Conditional name of manufacturer groups	Strength of diamonds under static compression, *P*, N	Specific magnetic susceptibility, $\chi \cdot 10^{-8}$, m^3/kg
	500/400	
1	402	25.0
2	436	0.5
	250/200	
1	246	0.9
2	275	0.5

That is why the purpose of this research is to study the possibilities of improving the physical and mechanical properties of diamond grinding powders used in dressing tools.

For the obtained powders AC65-AC250, the following physical and mechanical properties before and after heat treatment have been determined: strength as destructive load under static compression at room temperature (P, N) and after heat treatment P_{AT}) at 800 °C and 1100 °C, by the methods of DSTU 3292-95; heat resistance estimated by the coefficient of thermal stability (C_{TS}) and the coefficient of strength uniformity (C_{su}); and specific magnetic susceptibility (χ), by measurements. It should be noted that the coefficient of strength uniformity (C_{su}) of a certain grain size and grade has been determined based on the total content of grains, the destructive load of which is within the range of strength for the nominal grade in accordance with DSTU 3292. The elemental composition of impurities and inclusions in diamond powders has been determined by X-ray fluorescent integrated analysis, with the use of *BS-340* scanning electron microscope and *Link-860* energy-dispersive X-ray analyzer.

The effect of heat treatment has been studied on AC200 diamonds with grain size 500/400 and 250/200. The diamond powders are separated in a magnetic field of different intensity (from 0 to 20 kA/m^2) to obtain fractions of powders, which differ in specific magnetic susceptibility. After the separation, the obtained powders are thermally treated in an inert medium, at a temperature of 800 °C and 1100 °C. Before the heat treatment, all samples undergo chemical treatment to remove impurities from the surface of diamond grains.

The results of the separation of AC200 diamond grinding powders with grain size 500/400 and 250/200 in a magnetic field of different intensities are shown in Fig. 2 (*a*, *b*). Fig. 2 features AC200 diamond grinding powders with grain size 500/400 and 250/200 separated in a magnetic field into several fractions, with diamonds of the magnetic fractions (magnetic 1), which have a high specific magnetic susceptibility, and the nonmagnetic fractions differing in what? 11.5 times for grain size 500/400 and 7.8 times for grain size 250/200.

The results of determining the physical and mechanical properties of diamond grinding powders of the original magnetic and nonmagnetic fractions of grain size 500/400 and 250/200 after heat treatment at 800 and 1100 °C are presented in Table 4.

It is seen that in both diamonds, with grain size 500/400 and 250/200, as the content of intracrystalline metal inclusions in diamond crystals grows, their magnetic properties get stronger. The crystals with the larger grain size 500/400 contain more intracrystalline metal inclusions, consequently, they possess higher specific magnetic susceptibility. The increase in the content of intracrystalline metal inclusions in the diamond crystals of all the studied systems leads to a decrease in the strength characteristics after heat treatment at both 800 °C and 1100 °C. For the diamond crystals with lower content of intracrystalline impurities and inclusions (fractions 3 and below), after heat treatment at 800 °C, there is reported a slight (approximately 5%, at most) increase in strength, which can be explained by a decrease in internal stresses in diamond crystals as a result of heat treatment. The greater is the content of impurities and inclusions, the more intense is the decrease in the strength of diamond crystals. In addition, as follows from Table 4, the separation of diamond grinding powders with grain size of 500/400 and 250/200 in a magnetic field into fractions with different specific magnetic susceptibility and, accordingly, different content of intracrystalline metal inclusions stimulates the separation of diamond powders by strength. In this separation, there are distinguished the powders that differ in strength by 10—30%, at room temperature, and those more uniform in terms of strength by at least 25% for both grain sizes, as compared with the above.

Thus, the separation of diamond powders in a magnetic field and the separation of grinding powders with different content of intracrystalline impurities and inclusions in diamond crystals with grain size 500/400 and 250/200 contribute to the overall increase in heat resistance of diamond grinding powders of both grain sizes. The most heat-resistant are high-strength powders with a lower content of intracrystalline impurities and inclusions.

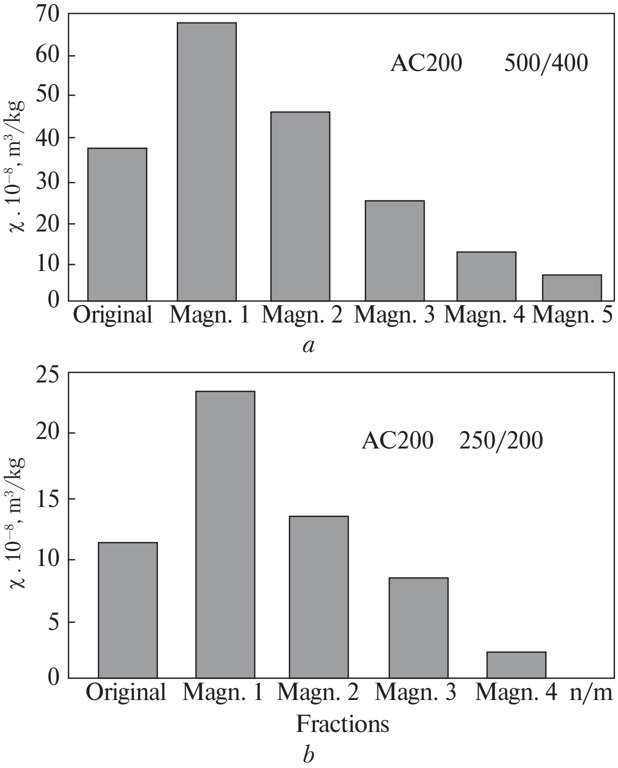


Fig. 2. The results of the separation of AC200 diamonds with grain size 500/400 (*a*) and 250/200 (*b*) in the magnetic field

During the treatment, the temperature in the diamond contact area may reach 1000 °C; the diamonds are treated in the air environment. In this regard, the study of the corrosion resistance of diamonds in the air during high-temperature treatment is quite relevant. Usually, the heat resistance of powders of superhard materials, including synthetic diamond powders, is determined by the ability of their grains to maintain the strength properties as a result of heat treatment at a certain temperature. To develop methods for making tools, it is necessary to use thermally strong grains of diamond grinding powders. Therefore, the kinetics of the oxidation process of high-strength diamond powders synthesized with the use of ferroalloys in the air environment, at the temperature conditions of the diamond tool has been further studied.

The effect of gas-phase oxidation has been studied in the air and inert media environments, with the use of diamond powders with different dispersion, which are synthesized in iron-nickel-carbon, iron-cobalt-carbon systems. For the study, the samples are made of high-strength diamonds AC200 grain size 250/200, 315/250, and 400/315. Previously, before the oxidation process, the diamond grinding powders were separated in a magnetic field of different intensity with the separation of magnetic and nonmagnetic fractions of powders, which differ in specific magnetic susceptibility (χ) and, accordingly, in the content of intracrystalline metal inclusions (β). The samples of diamonds with different grain sizes are oxidized at a temperature of 900 °C and 950 °C for different times from 10 minutes to 6 hours. Under the same conditions, the diamond powders are processed in the argon atmosphere. The oxidation of diamond grains is measured by the difference of their mass before and after oxidation. The results of experiments on the oxidation of diamond grinding powders of different grain sizes in the gas environments have been compared by the difference in the oxidation rate of diamonds (V, g/sec) for a weight loss of 10%.

After the separation of diamonds with grain size 315/250 in a magnetic field for each growth system we have made samples of diamonds with the magnetic, nonmagnetic, and original fractions to be subjected to thermal oxidation at a temperature of 900 °C, in the air and gas environments. The obtained diamond samples are used to determine the strength of static fracture of diamond grains and the rate of their oxidation in the air and inert gas environments, as well as the specific magnetic susceptibility and the content of intracrystalline metal inclusions. The results of these studies are given in Table 5.

Table 5 shows that the diamond grinding powders synthesized in the Fe—Ni—C and Fe—Co—C systems of the magnetic, nonmagnetic, and original fractions, which differ in the specific magnetic susceptibility, strength, and content of intracrys-

Table 4. **Physico-Mechanical Properties of Diamonds, Grain Sizes 500/400 and 250/200**

Separated fractions	$\chi \cdot 10^{-8}$, m^3/kg	The total content of inclusions on the diamond surface after heat treatment, % wt.	Destructive load under static compression, at different temperature, N			C_{TS}, %	$C_{su.}$, %
			Room temperature	800 °C	1100 °C		
500/400							
Magnetic 1	65.7	0.839	318.9	300.8	239.2	65	72
Magnetic 2	44.7	0.627	356.7	341.5	281.8	79	79
Magnetic 3	23.9	0.506	379.9	380.9	341.9	90	88
Magnetic 4	11.6	0.437	427.8	431.5	397.5	93	88
Magnetic 5 (nonmagnetic)	5.7	0.334	467.2	475.9	444.5	95	89
Original	35.6	0.445	408.9	—	341.3	83	69
250/200							
Magnetic 1	22.7	0.568	174.3	171.3	148.8	76	79
Magnetic 2	12.8	0.412	195.8	194.4	187.5	94	84
Magnetic 3	7.9	0.329	228.9	230.8	217.5	95	89
Magnetic 4 (nonmagnetic)	2.9	0.235	250.7	265.7	240.7	96	90
Original	10.7	0.356	225.7	—	198.6	88	74

talline inclusions have similar the oxidation rates both in the air and in the inert gas environments. The oxidation rate of the diamonds of magnetic fractions of Fe—Ni—C and Fe—Co—C systems is approximately 2 times higher than that of the diamonds of nonmagnetic fractions.

Based on the above data, the heat resistance to oxidation in the air environment and the strength of diamond powders depend on the concentration of metal impurities in them. The greater is the content of metal impurities in the diamond powders, the lower are the heat resistance to oxidation and the strength. In this regard, we have proposed a special additional thermochemical treatment of diamond powders, which may significantly reduce the concentration of metal impurities thereby increasing the diamond powder resistance to oxidation in the gas environment and improve the performance of diamond tools.

Therefore, the physical and mechanical properties of high-strength (AC160—AC250) synthetic diamond grinding powders used in precision dressing tools have been further studied. The characteristics of diamond grinding powders AC250, AC200, and AC160 synthesized in the Fe—Ni—C system are given in Table 6.

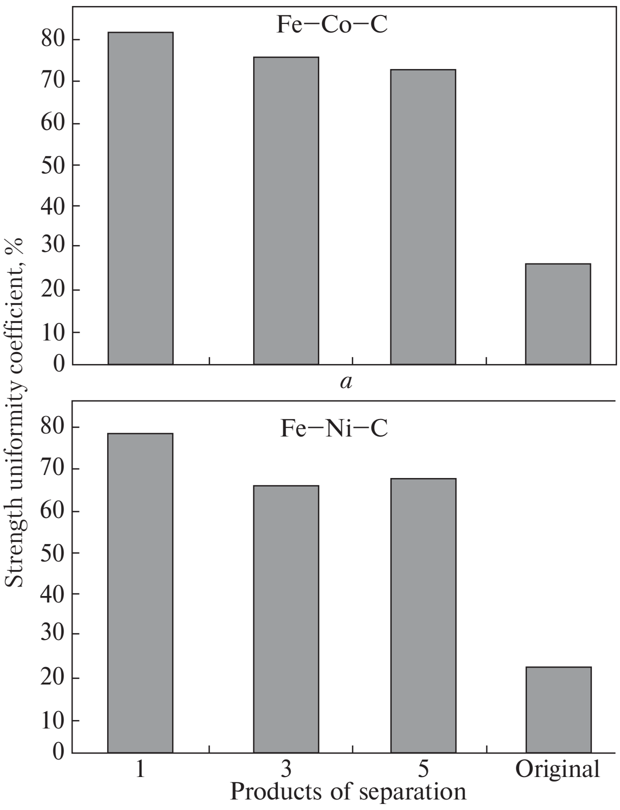
Table 6 shows that the strength of diamond grinding powders AC250—AC160 varies depending on the content of inclusions in them. As the content of inclusions increases from 0.331 to 0.617 atom. %, the strength decreases from 414.2 to 305.5 N, at room temperature, and from 393.5 to 220.0 N, after heat treatment. The thermal stability coefficient of diamonds (C_{TS}) decreases from 95 to 72%. Based on C_{TS} the thermal stability diamonds has been categorized as high (HT), for AC250 and AC200, and medium (MT), for AC160. The strength uniformity coefficient of synthetic diamond grin-

Table 5. **Results of the Studies of Grinding Powders Made of Diamonds Synthesized in Different Systems**

Fraction	$\chi \cdot 10^{-8}$, m^3/kg	β, % wt.	Strength, *P*, N	Oxidation rate, *V*, g/s	
				Air	Argon
			Fe–Ni–C system		
Magnetic	22.7	0.538	216.1	8.9	4.2
Nonmagnetic	3.0	0.315	354.9	3.9	2.2
Original	9.8	0.427	289.3	7.7	5.9
			Fe–Co–C system		
Magnetic	49.5	0.835	189.0	10.3	4.8
Nonmagnetic	11.2	0.452	319.0	5.4	2.3
Original	29.6	0.624	267.0	7.8	6.7

Table 6. **Properties of Diamond Grinding Powders with Grain Size 400/315 of Different Grades, Which Are Synthesized in the Fe–Ni–C System**

Property	Grades according to DSTU 3292 and TU U 28.4–05417344–2003		
	AC250	AC200	AC160
Specific magnetic susceptibility, $\chi \cdot 10^{-8}$, m^3/kg	3.2	10.2	24.7
Strength at room temperature, *P*, N	414.2	358.0	305.5
Strength after heat treatment, *PHT*, N	393.5	304.3	220.0
Thermal stability coefficient, C_{TS}, %	0.95	0.85	0.72
Category of thermal stability	BT	BT	CT
Coefficient of strength uniformity, C_{su}, %	76	64	48
Surface defect coefficient, K_a, %	0.05	0.12	0.23
Content of inclusions, β, atom. %	0.331	0.439	0.617



b

Fig. 3. Strength uniformity of grinding powders made of synthetic diamonds with grain size 400/315 synthesized in the systems: *a* – Fe–Co–C and *b* – Fe–Ni–C

ding powders varies from 76 to 48%. As the content of inclusions increases, the specific magnetic susceptibility of diamonds grows from 3.2×10^{-8} to 24.7×10^{-8} m^3/kg. The surface defect coefficient of grinding powders of different grades, based on the surface activity coefficient, ranges from 0.05 to 0.23%.

In general, the diamond crystals of all systems, which contain less intracrystalline impurities and inclusions, have a higher strength. To improve the strength characteristics and their uniformity, it is necessary to sort out the diamond grinding powders in a special way. Therefore, to raise the efficiency of separation of synthetic diamond grinding powders synthesized with the use of ferroalloys, the method of adhesive-magnetic sorting of diamond grinding powders has been improved. The proposed method provides for the surface treatment of the grains of diamond grinding powders by applying electrically conductive fine particles and their adhesive fixation on the surface of the diamond grains to create the required electrical properties and conditions of the powder separation process in an electric field. To raise the efficiency of separation of synthetic diamond grinding powders synthesized with the use of ferroalloys, there has been developed a method for separation of diamonds based on their surface defects by selective application of electrically conductive fine particles due to adhesion forces, their fixation on the surface of powder grains (to enhance the natural electric properties), which enables separating the diamond grains in an electric field into several fractions and improving the selectivity of their separation by strength characteristics. The electrically conductive fine particles with a size of at most 1000 nm are applied on the surface of diamond grains at a concentration of these particles of at least 5%. As a result, it makes it possible to distinguish diamond grinding powders with increased strength. Hence, after the separation of diamond grains, grades from AC125 to AC300, in product No. 1, from AC125 to AC250 in product No. 3, and from AC65 to AC200 in product No. 6 have been distinguished.

Due to the separation by surface defect coefficient of grinding powders of diamonds with grain size 400/315, which are synthesized in different Fe—Co—C and Fe—Ni—C systems, the powders with the final fractions (1 and 6) differing in strength from 3.0 to 1.4 times and in heat resistance from 1.3 to 1.7 times have been obtained. The powders obtained after sorting are characterized by a high heat resistance and strength uniformity.

Fig. 3 shows the strength uniformity of grinding powders of diamonds with grain size 400/315, synthesized in Fe—Co—C and Fe—Ni—C systems. It is seen that the diamond grinding powders differ 4.2—3.0 times for Fe—Ni—C system and 3.5—2.4 times for Fe—Co—C system from the original powders in terms of strength uniformity.

The research and production site for manufacturing the above-mentioned science-intensive precision diamond dressing tools created at the NAS of Ukraine (within the framework of R&D innovative project) enables meeting the needs of the machine-building enterprises of Ukraine, saving foreign currency that otherwise would be spent for the purchase of such tools, as well as attracting foreign currency revenues to the NAS as a result of entering the markets of other countries with such an effective science-intensive tool. This has made it possible not only to replace the imported tools manufactured by *CORUS* (Switzerland), *Shaundt and Reishauer* (Germany), and *Tyrolit* (Austria) in Ukraine (*Zorya-Mashproekt* (Mykolaiv), PJSC *Hydrosila APM* (Kropyvnytskyi), and PJSC Odessa Piston Rings Plant (Odesa)), but also to enter the markets of Belarus (contract with JSC Belarus Automobile Plant (Zhodino), Moldova (contract with JSC Moldova Metallurgical Plant (Rybnitsa)), and Bulgaria (contract with Asenovgrad Plant (Asenovgrad)). The innovative developments aiming at improving the physical and mechanical properties of high-strength diamonds, which have been described herein, allow raising the performance of this effective dressing tool.

Conclusions

1. It has been shown that the separation of high-strength synthetic diamonds with grain size 500/400 and 250/200 in magnetic field of different strengths facilitates the production of grinding powders that differ in the content of intracrystalline inclusions, which leads to improving the physical and mechanical properties: increase in strength, strength uniformity, and heat resistance.

2. It has been established that after heat treatment at a temperature of 800 °C, for the diamonds with a lower content of intracrystalline inclusions due to reducing the internal stress in the diamond crystals, there is reported a slight increase in the strength of at least 5%. The thermal stability of diamonds of all studied systems decreases, as the content of intracrystalline inclusions in diamond crystals increases.

3. It has been shown that as the content of intracrystalline metal inclusions in diamonds increases, so does the rate of their oxidation increases in the magnetic fractions.

4. The proposed methods for obtaining diamond powders with a minimum content of metal inclusions have enabled enhancing the corrosion resistance of diamonds, increasing the resistance to oxidation in the gas environment, and improving the performance.

5. The innovative method for sorting the diamond grinding powders synthesized with the use of ferroalloys by grain surface defects has been developed. It has been shown that the physical and mechanical properties (strength and heat resistance) of the diamond grinding powders synthesized in different Ni—Mn—C, Fe—Co—C, and Fe—Ni—C growth systems, both before and after high-temperature treatment, decreases 3—5 times, as the content of intracrystalline impurities and inclusions, especially metallic ones, in them increases more than twice. The use of such improved diamond grinding powders allows raising the efficiency of high-precision diamond dressing tools.

Received 11.02.2021
Revised 11.05.2021
Accepted 04.06.2021

В.І. Лавріненко [1] **(**http://orcid.org/0000-0003-2098-7992),
Г.Д. Ільницька [1] **(**http://orcid.org/0000-0001-5124-1646),
М.М. Шейко [1] **(**http://orcid.org/0000-0001-7490-7674),
В.Л. Доброскок [2] **(**http://orcid.org/0000-0003-4090-6272),
Є.В. Островерх [2] **(**http://orcid.org/0000-0002-8926-1324),
В.Ю. Солод [3] (http://orcid.org/0000-0002-7516-9535)
[1] Інститут надтвердих матеріалів ім. В.М. Бакуля НАН України,
вул. Автозаводська, 2, Київ, 04074, Україна,
+380 44 468 8632, secretar@ism.kiev.ua
[2] Національний технічний університет «ХПІ» МОН України,
вул. Кирпичова, 2, Харків, 61002, Україна,
+380 57 700 1564, omsroot@kpi.kharkov.ua
[3] Дніпровський державний технічний університет МОН України,
вул. Дніпробудівська, 2, Кам'янське, 51918, Дніпропетровська обл., Україна,
+380 569 56 0667, science@dstu.dp.ua

ПОЛІПШЕННЯ ЕКСПЛУАТАЦІЙНИХ ХАРАКТЕРИСТИК СИНТЕТИЧНИХ АЛМАЗІВ ДЛЯ ВИСОКОПРЕЦИЗІЙНОГО АЛМАЗНОГО ПРАВЛЯЧОГО ІНСТРУМЕНТУ

Вступ. Підприємствам машинобудування України, особливо двигунобудівним та авіаційним, потрібен прецизійний алмазний правлячий інструмент. Для його ефективного використання необхідним є застосування в них порошків синтетичного алмаза високої якості з контрольованими характеристиками показників міцності та термостійкості, а також геометричних розмірів зерен.

Проблематика. Синтетичні алмази синтезуються в різних ростових системах, тому суттєво різняться за наявністю в них внутрішньокристалічних домішок і включень, а відтак і за різними властивостями.

Мета. Дослідження можливостей поліпшення фізико-механічних властивостей алмазних шліфпорошків шляхом ефективного сортування за дефектністю поверхні зерен шліфпорошків.

Матеріали і методи. В алмазних порошках АС65–АС250 визначали фізико-механічні характеристики: міцність при статичному стисненні, коефіцієнт однорідності за міцністю, термостійкість та питому магнітну сприйнятливість. Елементний склад домішок і включень у порошках визначали рентгенофлуоресцентним інтегральним аналізом за допомогою растрового електронного мікроскопу «BS-340» та енергодисперсійного аналізатора рентгенівських спектрів «Link-860».

Результати. Показано, що розділення алмазів в магнітному полі різної напруженості сприяє отриманню шліфпорошків, які різняться між собою за вмістом в них домішок і включень, а відтак і змінюються їхні фізико-механічні характеристики. Загалом кристали алмазів всіх систем, що містять меншу кількість домішок і включень, мають вищу міцність. Для досягнення цього здійснюється спеціальне сортування шліфпорошків алмаза. Для цього удосконалено спосіб адгезійно-магнітного сортування алмазних шліфпорошків, де передбачено обробку поверхні зерен шліфпорошків шляхом нанесення електропровідних тонкодисперсних частинок і адгезійного закріплення їх на поверхні зерен алмаза для створення набутих електричних властивостей.

Висновки. Застосування в інструменті таких спрямовано поліпшених алмазних шліфпорошків дозволяє підвищити ефективність алмазного правлячого інструменту.

Ключові слова: прецизійний правлячий інструмент, шліфпорошки синтетичного алмаза, дефектність поверхні синтетичного алмаза, ростові системи синтезу, сортування, поліпшення експлуатаційних характеристик синтетичних алмазів.