EXPLOITATIVE DESTRUCTION FEATURES FOR DETONATION ULTRA-DISPERSED DIAMONDS OF INITIAL METALLIC PROTECTION FOR ABRASIVE POWDER GRAINS TO DIAMOND-SPARK GRINDING TOOLS

Sen. Staff Scientist Yury **GUTSALENKO[1], Prof. PhD. Eng.** Cătălin **IANCU[2], Prof. PhD. Eng.** Sergey **BRATAN[3]**
[1]Nat. Tech. Univ. "Kharkov Polytechnic Inst.", gutsalenko@kpi.kharkov.ua,
[2]"C-tin Brâncuşi" Univ. of Tg-Jiu, ciancu@utgjiu.ro
[3]Sevastopol State Univ., serg.bratan@gmail.com

Abstract: *The problem of exploitation of diamond grinding wheels with metal coating for their grains including* detonation *ultra-dispersed diamonds to increase functional reliability to maintain the initial integrity of grains in the pressing and sintering of diamond-metal composites in the tool production is considered. One problem is that the presence of* detonation *ultra-dispersed diamonds in the grain metal coating of diamond powders not only improves the coating functional reliability in protection from destruction in the subsequent pressing and sintering in the production tool, but also resistance of such coating to the opening of the diamond cutting basis of the grains on the grinding wheel working surface that come into working contact with the material being processed. An analysis of the features of an effective exploitative destruction of* detonation *ultra-dispersed diamonds in the metal coating using electric current in the tool of the diamond-spark grinding processes is presented.*

Keywords: diamond-spark grinding, grinding wheel, diamond-metal composite, diamond grain, protective metal coating, detonation ultra-dispersed diamond, electric current, destruction.

1. INTRODUCTION

Technological capabilities and advantages of diamond-spark grinding (DSG) by wheels on high-strength metal bonds [1] are connected with reliable retention of diamond grains that protrude above the bond, and managed update of the cutting relief based on the maximum use of the unique working potential of the super hard abrasives. Carried theoretical and experimental studies of the impact of diamond wheel cutting relief wear and update on the stability of the process and operation parameters of the DSG point to the decisive influence of the initial size, geometry, strength, wear resistance of the super hard grains as a part of diamond-metal tool composition on its potential working capacity, the intensity and resource of working exploitation.

Metal protection of the surface of synthetic diamond grains reinforced by including of detonation ultra-dispersed diamonds (UDD) in the coating contributes to the morphometric preservation of grains in pre-operating period of their life cycle. The experience of increase the efficiency of DSG by wheels with the initial surface metallization of superhard abrasive grains is known [2]. Therefore, the including of superhard component in the form of UDD into the composition of the metal coating of the diamond grains for the tools of DSG opens new perspectives in improving the working life of grinding wheels and the technological possibilities of this technological method of high-performance complete machining.

In NTU "KPI" developed a practical technology of abrasion-resistant metallization of diamond grains with the introduction of UDD, and there are obtained the data on the possibility of pressing and sintering of grinding wheel diamond-metal working compositions under such a composite coating without destroying them with diamond grains under such a composite coating without destroying them [3].

2. PROBLEM AND PURPOSE

Acting in the known role [4] of powerful structure-forming agent, significantly amplifying the functional properties of the coating at the stage of tool production, detonation UDD in its composition on the grains of the grinding wheel working surface in the operational technological use at the same are the centers of high wear resistance to opening of diamond cutting basis of the grains.

The present study continues the work of the authors in the direction of rational use of functional coatings in technique and tools of DSG [5] as well as consideration of the characteristics and applications of thin structures of superhard carbon allotropes [6]. It aim is to show the principal features and possibilities of effective operational destruction of detonation UDD under the action of an electric current in the metal coating, which carried out its protective function and requires opening in workflows of managed DSG.

3. PHYSICAL BASIS AND TARGET LOGISTICS

By the time of the first publication (1988, [7]), that reveals the essence of the method of fabrication of UDD during a quarter of a century development in the USSR, from the first experience of explosive synthesis of UDD in 1963, carried out by the Russian scientists in the field of gas dynamics K. V. Volkov, V. V. Danilenko, and V. I. Elin from National Scientific Research Institute of Technical Physics (now Russian Federal Nuclear Center) in the science city of Chelyabinsk region, Snezhinsk (Chelyabinsk-70), their industrial production, the annual volume of which amounted to about 10 million carats has already existed on the basis of the scientific production association "Altai" [8]. In Ukraine, an independent pilot synthesis of UDD has been carried out at the Institute for Problems of Materials Science (Kiev) under the leadership of V. I. Trefilov [9]. Since 1992 industrial production of UDD has been organized in closed corporation "Alit" (Zhitomir) [10]. Research and production enterprise "SintA" LLC, using original technology of synthesis and chemical purification, engages in fabrication of UDD in Kharkov [11].

It was first established in the study [12] that UDD has tetragonal crystal lattice with the parameters $a = 0.3585$ nm and $c = 0.345$ nm, and morphological samples obtained in this manner are gas-filled hollow spheres of diamond particles having an average inner radius of shell 1.894 nm and an external radius of shell 2.547 nm. These particles up to 4-6 nm in size crystallize in the diamond phase, at the same time being sintering, forming secondary fractal structure. At that gas-filled cavities inside the particles are formed during crystallization process.

Interaction with the gas medium of the explosion chamber leads to the oxidation of the surface carbon atoms. The sources of gas emission of UDD are internal and interparticle closed cavity and oxidized carbon atoms. The final product contains carbon (from 84.0 to 89.0 wt.%), hydrogen(from 0.3 to 1.1 wt.%), nitrogen (from 3.1 to 4.3 wt.%), oxygen (from 2.0 to 7.1 wt.%) [8].

Role activation of cutting diamond grains in electrical contact of the grinding wheel with the workpiece due to their metal coating corresponds successfully to the approved concept of DSG with the introduction of additional energy in the form of direct current in cutting area [13] and at that with soft electric mode of excitation of electrical discharges on the mechanism of sliding electrical contacts [14].

It can be assumed that at DSG (e.g., with arrangement of current supply to the cutting area by the scheme [13]) the flow of electric current in the bulk of metal coating of diamond grain will be accompanied by an intensification of density of the electric field around the diamond nanoparticles perceived similarly to the pores in the technologies of ceramics electroconsolidation under pressure according to the SPS method [15], with an increased probability of discharge attacks of gas-filled cavities inside the diamond nanoparticles, initiation of ozone into them, realizing increased oxidative activity by capturing of carbon, etc. [16].

The behavior of the electric current in the field of UDD particles interstitial into a solid metal body has not been previously predicted and studied, but is of considerable theoretical and practical interest from the position of an impact on the contact properties of the hollow nanodiamond particles and their structure formation function in the surrounding bulk of metal coating.

In analytical and synthetic structures of the general picture of spark-discharge displays of DSG with participation of metal-coated diamond grains containing UDD in the coating composition, we should not evidently eliminate the possibility of the known in nature air-gas medium of local fields of static electricity, the energy which can be released by the sparks [17], addressing this possibility to nonvacuum-processed enclosed spaces under the diamond cover of UDD with its post-discharge mechanical deformation and destruction.

The final product in the conventional technologies of UDD synthesis in metal chambers, in addition to the non-diamond phase of latent carbon [18] and gas component, contains the results of the interaction of detonation products with the walls of the chamber, steel as usual. The research [12] of condensed explosion products fabricated by the detonation of explosives consisting of the alloy of 1,3,5-trinitrotoluene with cyclotrimethylenetrinitramine exploded in atmosphere of products of the previous explosion of the same explosive, found the content of incombustible impurities of oxide Fe (III), iron carbide and α-iron within limits of 4.2-6.5 %, with the following distribution of the intensities in the spectrum among the iron impurities: the contribution of the line of α-iron is 29-43%, magnetite - 36-48%, certain ions Fe (III) - 16-27 % [12]. Of course, the specifics of these results comply with the conditions of research [12] (the volume of the explosion chamber 3.05 m^2, the oxygen content in it - up to 6 vol.% , the load weight - 0.65 kg; the temperature of the chamber walls – up to 363 K, the ratio of the mass of condensed products of explosives detonation – 9 (trinitrotoluene): 1 (cyclonite) at 8 wt.% of diamond nanophase; etc.). However, the structure and order of the values of the obtained data make it possible to assume a radical change of conductivity conditions in nanodiamond covers, favourable for their electric-discharge cleaning like [19] under DSG conditions, possibly with sliding discharge along the boundaries [20].

Dimensional assessment of morphometry the secondary fractal structures of UDD is less than 10 nm, and in the initial morphological assessment ratio of the average size of the diamond wall and the whole particle in its interpretation by spherical model on experimental data [12] is virtually 1:4. With this in mind, as well as a simple ratio of overall dimensional evaluation of fractal structure of UDD (less than 10 nm) and the lower limit of granularity for powders of synthetic diamonds in the recommendatory practice of grinding wheels on metal bonds (40 μm, according to the basic standard for diamond powders of any genesis [21], as well as on detailed exposition of this standard in its synthetic part [22]), i. e. less than 1:1000, it can be used overheating by bursts of electrical current (e.g., electric-discharge) to achieve a known graphitization temperature zone (about 1000 C for UDD [23]) with a duration of action which is destructively critical in full only for ultra-dispersed diamond fragments of detonation nature. At the same time significantly higher power of heat reset for synthetic diamonds (approximately 600 W/(m·K) [24]) compared with the surrounding bond metal matrix (for most typical brands on the copper-tin or copper-zinc-aluminum-based it is about 20...40 W/(m·K) [25]) in the temperature range close to the diamond graphitization will contribute to superhard preservation of diamond grains of grinding powder in the descending part of a thermal overload.

In the present case of operating sliding electrical contact between the grain metal covering and the electrically conductive material that is processed the potential energy intensity of electrical discharges significantly reduced in contrast to the DSG by wheels without an initial metal covering of the cutting grains. Therefore, erosion destructions of diamond grain metal coating and wheel metal bond in a sliding contact with processed material are much less intense. This implies a low probability of tipping out an wear-free UDD as a result of a single electric discharge in sliding contact between the metal coating of the grinding powder grains and processed material. Therefore, taking into account and the use considered above technological capabilities of DSG in operational liberation from metal coating of wheel grains with UDD is an important additional source of increasing the efficiency of the processing by tools of superhard abrasives with preoperational preserve the original integrity of the individual grains.

4. CONCLUSION

Electrophysical features of DSG provide an opportunity to increase the efficiency of operation of the tool with metal coating of superhard abrasive grains which includes UDD to increase the functional reliability through the preservation of the integrity of the original grains during compaction and sintering of diamond-metal composites.

These features allow intensify the liberation of superhard basis of cutting grains from metal coating, which carried out its provisional protective function. This is done by deactivating of UDD locations as the centers of increased wear resistance which increase the resistance to the coating stripping.

The nature of these opportunities is the electric, and is contained, firstly, in an intensification of density of the electric field around the non-conductive hollow nanoparticles of the UDD that promotes to electrodischarge attack and post-discharge mechanical deformation and destruction of these nanoparticles. Secondly, it is permissible to perform a short electrical pulse heating with sufficient power and duration to graphitization of UDD shells that suppresses its wear resistance.

REFERENCES

[1] **Gutsalenko, Yu.** Stable diamond grinding // Fiability & Durability – Targu Jiu: Editura "Academica Brancusi". – No. 1/2010. – PP. 19-24.

[2] **Malykhin, V. V.** Improving the efficiency of co-grinding by diamond wheels of hard alloys containing tungsten, and steel / Abstract of a thesis for a PhD degree: Print. − Kharkov: KhPI, 1985. – 26 p. – In Russian.

[3] **Babenko, Y. A.** Improving of efficiency of diamond wheels based on polymeric and ceramic bonds / Dissertation for a PhD degree: Manuscript. − Kharkov: NTU "KhPI", 2014. – 203 p. – In Russian.

[4] **Baraboshkin, K. S.** Investigation of the formation of the texture of detonation nanodiamonds for designing and creating of highly efficient composite materials /

Dissertation for a PhD degree: Manuscript. − Biysk: Federal Research and Production Center "Altai", 2006. – 136 p. – In Russian.
[5] **Bratan, S. M., Iancu, C., Gutsalenko, Yu. G., Sevidova, E. K.** Coatings for electrically insulating protection of grinder faceplate // J. of the Sevastopol Nat. Tech. Univ. – Iss. 150/2014, Mechanical Instrumentation and Transport. – Sevastopol: SevNTU, 2014. – PP. 28-31. – In Russian.
[6] **Iancu, C., Stăncioiu, A.** Graphene: a new material // Fiability & Durability. – Targu Jiu: Editura "Academica Brancusi". – No. 1/2011. – PP. 31-34.
[7] **Lyamkin, A. I., Petrov, E. A., Ershov, A. P., Sakovich, G. V., Staver, G. V., Titov, V. M.** Production of diamonds from explosives // Reports of the USSR Academy of Sciences. – 1988. – Vol. 302, No. 3. – PP. 611-613. – In Russian.
[8] **Vereshchagin, A. L.** Properties of detonation nanodiamonds. – Barnaul: Publishing House of the Altai State Tehn. Univ., 2005. – 134 p. – In Russian.
[9] **Trefilov, V. I., Savvakin, G. I., Skorokhod, V. V., Solonin, Yu. M., Hrienko, A. F.** Features of the structure of the ultra-dispersed diamonds from high-temperature synthesis in an explosion // Reports of the USSR Academy of Sciences. – 1978. – Vol. 239, No. 4. – PP. 838-841. – In Russian.
[10] **Danilenko, V. V.** From the history of the discovery of nanodiamonds synthesis // Solid State Physics. – 2004. – Vol. 46, Iss. 4 – PP. 581-584. – In Russian.
[11] R&D Manufacturing Enterprise "SintA" LLC, official website. – http://nanodiamond.com.ua.
[12] **Vereshchagin, A. L.** Synthesis and properties of refractory inorganic compounds and phases obtained in the modes of combustion and detonation degassing condensed compositions / Dissertation for a doctor of sciences degree: Manuscript. − Biysk: Biysk Technol. Inst. (branch) of Altai State Tech. Univ., 2004. – 248 p. – In Russian.
[13] **Fadeev, V. A.** Diamond grinding of hard metals with the introduction into the cutting zone of DC additional energy / Dissertation for a PhD degree: Manuscript. − Kharkov: Kharkov State Polytechnic Univ., 1995. – 273 p. – In Russian.
[14] **Namitokov, K. K.** Electroerosion phenomena: Monograph. – Moscow: Energy, 1978. – 456 p. – In Russian.
[15] **Gevorkyan, E. S., Gutsalenko, Yu. G.** Features and place of electric consolidation by direct action of the AC in the methods of submicron and nanopowder sintering under pressure // J. of Nat. Tech. Univ. "Kharkov Polytechnic Inst.", Iss.: Technologies in mechanical engineering. – 2010. – No. 49. – PP. 144-161. – In Russian.
[16] **Gevorkyan, E. S., Gutsalenko, Yu. G.** Genesis of tungsten semicarbide expansion in tools in tungsten-ceramic tool composites under hot pressing with electro-consolidation of mono-carbide-based nanopowders // J. of Nat. Tech. Univ. "Kharkov Polytechnic Inst.", Iss.: Technologies in mechanical engineering. – 2010. – No. 53. – PP. 19-30. – In Russian.
[17] **Raiser, Yu. P.** Physics of the gas discharge. – Moscow: Science, 1992. – 536 p. – In Russian.
[18] **Woźniakowski, A. P., Shumilov, F. A., Ibatullina, A. H., Shugaley, I. V.** Ecological problems of obtaining of detonation nanodiamonds. Surface and functionalization // Ecological Chemistry. – 2012. – Vol. 21, No. 3. – PP. 164-167. – In Russian.
[19] **Guicciardi, S.** Composition dependence of mechanical and wear properties of electroconductive ceramics // Powder Metallurgy. – 1999. – No. 3-4. – PP. 32-41.
[20] **Bakshin, V. K., Kuzmin, G. P., Minaev, I. M., Rukhadze, A. A., Timofeev, N. B.**

Features of sliding discharge along the interface with different dielectric permittivity // Applied Physics. – 2005. –No. 6. – PP. 54-59. – In Russian.

[21] **GOST 9206-80**. Diamond powders. Specifications. Introduced July 1, 1981. – Moscow: Publishing House of Standards, 1989. – 17 p. – In Russian.

[22] **DSTU 3292-95.** Synthetic diamond powders. General specifications. Introduced Jan. 1, 1997. – Kiev: Derzhspozhyvstandart of Ukraine, 1997. – 151 p. – In Russian.

[23] **Ryabkov, N. L., Nikitin, E. V.** Synthetic ultra-dispersed diamonds (UDD) – materials of the XXI century // Nuclear Future: Security, Economics and Law: VI Int. Student Conference, St. Petersburg, Jan. 31 – Feb. 6, 2003. – Website of Int. Student Conference “Aurora Polaris”, http://www.polar.mephi.ru/ru/conf/2003/predloj/rjabk_tr.htm. – In Russian.

[24] **Synthetic superhard materials** / In 3 Vols. Ed. Board: **Novikov, N. V.** (Ed. in Chief), et al. – Vol. 1: Synthesis of superhard materials. – Kiev: Science Dumka, 1986. – 264 p. – In Russian.

[25] **Galitsky, V. N., Kurischuk, A. V., Murovsky, V. A.** Diamond abrasive tools on metal bonds for hard alloy and steel processing. – Kiev: Science Dumka, 1986. – 144 p. – In Russian.