ELECTROPHYSICAL ASPECT OF DESTRUCTION OF ULTRA-DISPERSED DIAMOND SHELLS IN THE COATING OF ABRASIVE GRAINS OF DIAMOND-SPARK GRINDING TOOL

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Abstract: *The mechanism of inclusion in abrasive cutting of diamond grains of grinding wheels, before sintering with a bond, protected by a thin metal coating with the inclusion of hollow shell nanostructures of detonation synthesis diamonds, is considered. A scheme of thermophysical gradient loading of shells under the influence of an electric field is presented. Qualitatively substantiated the position on the intensification of the cutting process at the microlevel using the technological method of diamond-spark grinding and other approaches to machining with diamond-abrasive tools with their inclusion in the electrical circuit together with the cutting zone.*

Keywords: grinding wheel, diamond grain, metal coating, embedded superhard nanostructures, electric field, gradient of strength, hollow diamond shell, thermomechanical destruction

1. INTRODUCTION

The increased cost of production of superhard abrasives and the demand for tools from them in the industry put forward increased requirements for their quality. One of the modern directions for improving the initial quality of diamond-abrasive tools is the use of metal coatings of grains with the inclusion of nanostructured detonation ultra-dispersed diamonds in the coating, to increase functional reliability to maintain the initial integrity of grains in the pressing and sintering of diamond-metal composites in the tool production [1, 2, 3].

However, 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.

Attention was drawn to this circumstance in the works [4, 5]. Overcoming the indicated problem of intensification of grinding at the micro level of individual cutting grains, which determines the performance of the process as a whole, was rightly associated in these works with the possibilities of the effective exploitative destruction of detonation ultra-dispersed diamonds in the metal coating using electric current in the tool of the diamondspark grinding processes. However, despite the fact that the later work [5] presented structural-geometrical, thermal and electrophysical schemes for the discussion of this problem, the corresponding explanatory part in these works is either insufficient [4] or completely omitted [5]. Here we decided to briefly fill this gap, in view of the prospects of the considered technological approach as a basic platform for new technical solutions for tools and grinding processes.

2. MAIN PROVISIONS

The key determinant of the technological approach in the problem under consideration is the release of the protective coating, which has fulfilled its protective function in the production of a grinding wheel and covers the superhard relief of diamond grains in their involvement in mass microcutting, from wear-resistant volumetric fragments of embedded superhard nanostructures of ultrafine diamonds, is that they are gas-filled shells. Such internally hollow diamond shells, from the first experience in 1963 at the closed Scientific Research Institute of Technical Physics in Chelyabinsk-70 [6], are produced by the explosive technology of detonation synthesis of diamond allotropes of carbon [7]. The bulk structures of the resulting ultradispersed diamonds have been sufficiently studied and described [8, 9], including the shape and size characteristics.

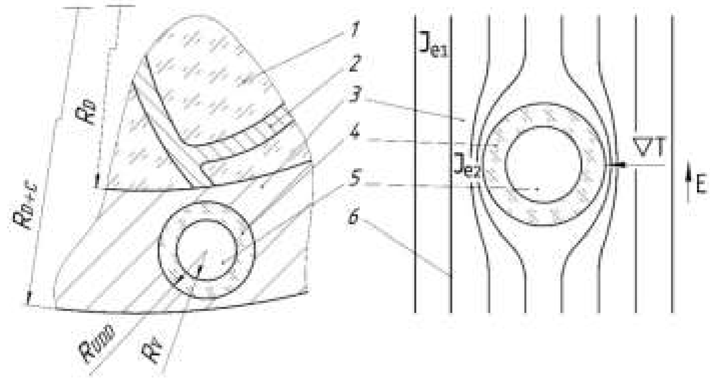
With regard to ultradispersed diamonds of detonation synthesis, it was established [10] that they have a tetragonal crystal lattice with parameters a = 0.3585 nm and c = 0.345 nm, and morphological samples obtained by this method are hollow gas-filled spheres of diamond particles with an average inner radius shells 1.894 nm and with outer 2.547 nm. These particles, up to 4-6 nm in size, crystallize into the diamond phase, simultaneously sintering, forming a secondary fractal structure. Gas-filled cavities inside the particles are formed during crystallization.

The final product of detonation synthesis of ultradispersed diamonds 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.%) [10]. Internal and interparticle closed cavities contain a gaseous medium. In addition, thermal desorption mass spectral analysis reveals the outgassing of carbon atom oxidation products on the surface of ultradispersed diamonds, which occurs due to interaction with the gaseous medium of the explosion chamber.

From the dimension of ultradispersed diamonds, it follows that their purpose as cutting grains of grinding wheels in productive processes of finishing machining, even at standard volumetric contents in the composition with a binder, is inexpedient. So, focusing on the average size and interpretation of a single ultradispersed diamond as a hollow sphere with a sphere radius R_{UDD} and a cavity radius R_{V} (Figure 1, *a*), the assumption of a minimum approximately half of its embedding in a bundle for the maximum protruding particle and the well-known Kragelsky criterion for the feasibility of the microcutting process from the ratio of the penetration depth into the material being processed and the radius of rounding of the working part of the cutting element (in practice, 0.1 ... 0.5 [11]), the possible thickness of a single cut falls within the range of 0.6 ... 2.5 nm. At the same time, the modern practice of effective microcutting with synthetic diamond abrasives, whose grains in a spherical model interpretation with a radius of R_{D} can serve as a functional basis for an initially metal-coated single tool cutting element with a radius of $R_{\text{D+C}}$ (Figure 1, *a*), even when processing especially difficult-to-cut tungsten monocarbide, in the reconstruction of diamond-spark grinding conditions indicates the thickness of single sections up to 3 μm [12].

To eliminate the structures of ultradispersed diamonds as hollow volumetric formations with thin shells in the composition of a solid body, technological approaches to suppressing internal porosity in materials of desired continuity are applicable. The model that we consider here (Figure 1, *b*) is based on the concept first proposed in [13].

During diamond-spark grinding (for example, when organizing the supply of current to the cutting zone according to the scheme [14]), the flow of electric current in the volume of the metal coating of diamond grain is accompanied by an increase in density of electric field with some strength E around diamond nanoparticles, which entail a violation of the homogeneity of the electric field and the occurrence of a temperature gradient ∇T due to a change in current density ($J_{e2}>J_{e1}$, Figure 1, *b*), and perceived similarly to pores in the technologies of electroconsolidation of ceramics under pressure according to the method of spark-plasma sintering, with an increased probability of discharge attacks and suppression of of gas-filled cavities inside diamond nanoparticles, initiation of ozone, which realizes increased oxidative activity due to carbon capture, etc. [15].



a *b*

a – structural and geometric scheme;
b – thermal and electro-physical scheme

1 – synthetic diamond grain;
2 – residual metal structures of catalytic synthesis of diamonds;
3 – diamond grain metal coating;
4 – diamond sheath of ultradispersed diamonds;
5 – gas-filled cavity of ultradispersed diamonds;
6 – electric field power lines

Fig. 1. Ultradispersed diamonds in metal coating of diamond grain of diamond-spark grinding tool

3. CONCLUSION

An approach using the technological similarity between the conditions for the rational organization of obtaining dense structures of increased homogeneity by spark-plasma sintering under pressure and diamond-spark grinding as a force effect on the processing object, with the integration of mechanical and electrophysical effects by both methods, is considered. From the point of view of advanced electrophysics of the working process, in addition to direct current supply to its zone, spark-plasma sintering and diamond-spark grinding are combined by electric discharge processing. This makes it effective and promising to take into account in its regulation the Paschen-Penning regularities on the energy minima of the ignition of an electric discharge in gaseous media, which provides additional opportunities for productivity and processing quality, as well as resource saving, especially in economically and environmentally attractive grinding processes with minimal or no liquid cooling.

The introduction of a superhard component in the form of ultrafine diamonds of detonation synthesis into the composition of the metal coating of diamond grains of diamond-spark grinding tools opens up new prospects both in increasing the resource of grinding wheels and in expanding the technological capabilities of this technological method of diamond-abrasive machining based on the mechanical and electrophysical interaction of the tool and grinding object.

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