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INCREASE OF EFFICIENCY OF DIAMOND GRINDING SUPERHARD OF MATERIALS

Abstract. *The analysis of algorithm of expert system of process of diamond grinding superhard of materials (SHPM) is given. For realization of the offered expert system the ways of grinding with the combined control of parameters of a working surface of diamond circles are developed. The designed ways of superhard polycrystallic material diamond grinding basing on control of a grinding wheel surface with usage of simulation of destruction processes of the system "polycrysta-grain–wheel bond" considered.*
Keywords: *superhard polycrystallic materials; destruction processes; diamond grinding; wheel working surface; combined direction; system "polycrystal - grain - bond".*

1. THE EXPERT SYSTEM OF THE SHPM GRINDING

A wide spectrum of different brands of superhard polycrystallic materials (SHPM) and nomenclature of diamond wheels hamper experimental definition of optimal conditions of SHPM grinding. It is connected with a great number of experiments and their high cost price. For definition of a range of such conditions the theoretical expert system, permitting to simplify this task, is created. The SHPM diamond grinding is process of mutual controlled destruction of system components "SHPM-grain-bond", and "grain-SHPM" can destroy mainly by friable microdestruction (productive process) or by the thermal-activated processes (ultra precision grinding).

The theoretical description of destruction processes of system units "SHPM-grain-bond" is extremely difficult, and practically it is impossible at raising on new output parameters of grinding. However estimated expert system permitting to narrow down a range of experimental researches for definition of optimal conditions of machining different SHPM by different wheels, can be created. The scheme of such expert system is represented on fig.1.

That the grinding process was steady, it is necessary, that the intensity of grain protrusion height was equal to speed of forced bond deleting (V_B). Thus working grain protrusion height from bond (h_p) should eliminate fallout of non-working grains, i.e. the capacity coefficient of grains should be more than 1 ($K_C \geq 1$). Thus h_p should be not less maxheight of bond microroughness (h_B) for exception of contact it with processed SHPM. At such working grain protrusion height it is easy to define number of grains in contact with processed SHPM.
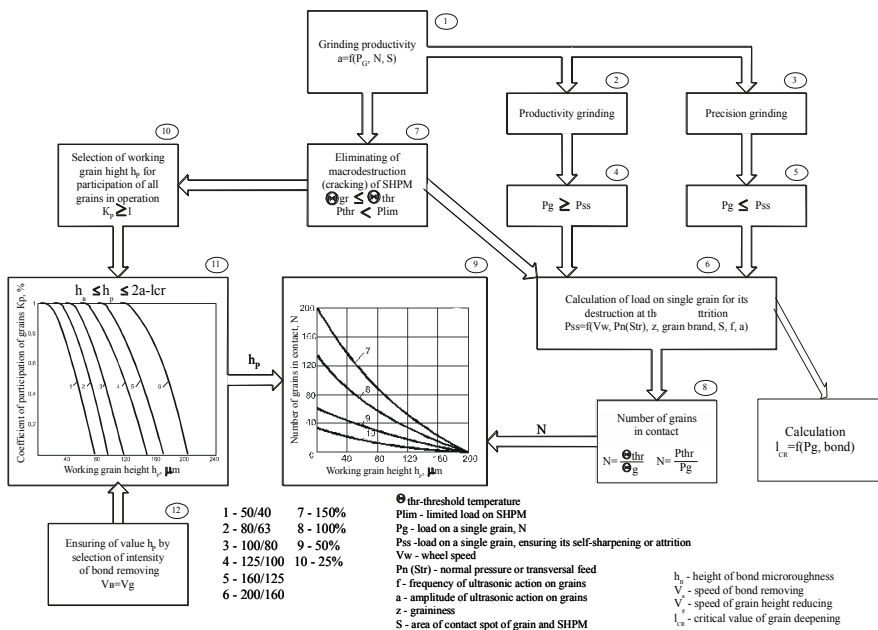
Figure 1 – Scheme of calculation algorithm of optimal SHPM grinding conditions

$$n = \frac{2a \cdot S \cdot K}{\pi \cdot d_{cp}^{2}} \tag{1}$$

where $a = h_P/l_G$; l_P - maximal value of a grain; S - single square; K - coefficient of diamond concentration in a wheel; d_{cp} - average grain size.

If the number of grains in contact for serially manufactured wheels is too great (that will not allow to put on each grain load, sufficient for friable self-sharpening of grains and for reason of cracking of a SHPM processed surface), it is necessary to decrease the concentration (for example, till 1-10%).

When we selected the number of grains in contact and received the load on a single grain, we solve the task of definition of diamond grain destruction intensity V_B in case of friable microdestruction in contact (productive grinding) or attrition of grains on wear platforms (ultra precision grinding). Thus the intensity of linear destruction of grains is caused both by contact with processed SHPM (V_{G1}) and ultrasonic effect in a direction zone (V_{B2}). Besides, according to physical-mechanical characteristics of bond, we define intensity "deepening" of grains to bond due to ultrasonic effect in a direction zone (V_{G3}). Then for stability of the

grinding process the speed of bond deleting in a direction zone (V_B) should be equal:

$$V_B = V_{G1} + V_{G2} - V_{G3} \tag{2}$$

The algorithm of such expert system represented on a fig.2.

Initial data: Physical-mechanical properties of SHPM and grains, P_N, V, z, K%, grain brand

Calculation of tension:
1. In grain: а) in contact with SHPM; б) dut to ultrasonic action in off-line zone.
2. In SHPM: а)for fragile microdestruction; б) during attrition.
3. In contact grain-SHPM.

Definition of conditions eliminating cracking of SHPM surface

Determination of intensity of productive SHPM removing

Determination of intensity of precision SHPM removing

Determination of intensity of linear grain wear and deepening grains into bond

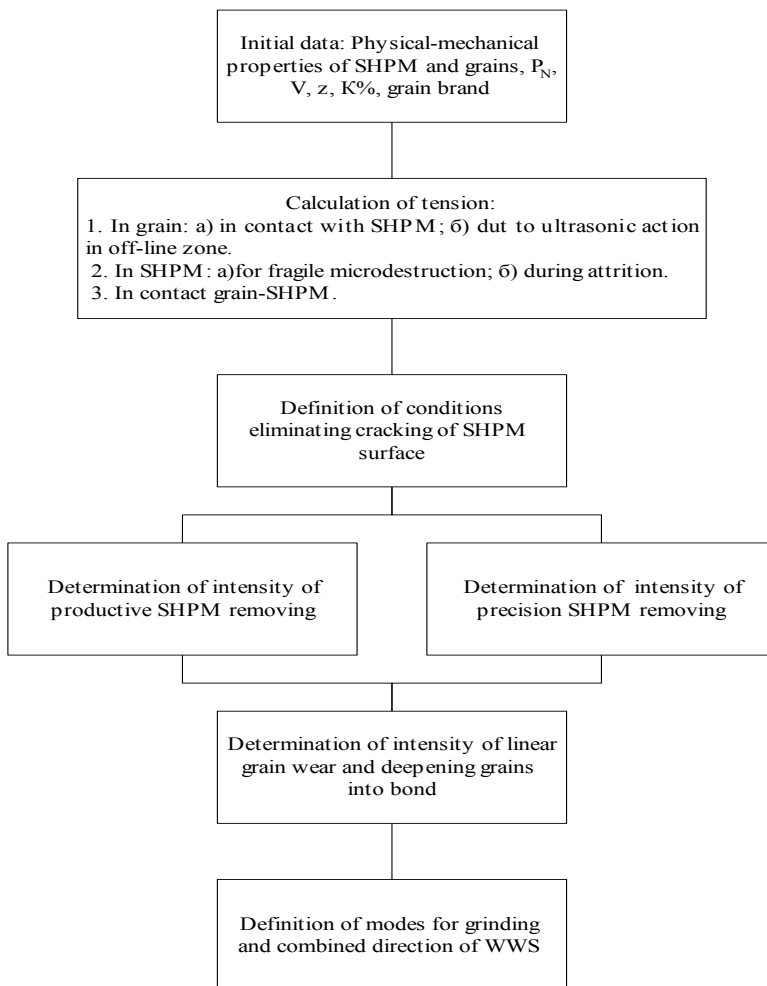Definition of modes for grinding and combined direction of WWS

Figure 2 – The block-scheme of expert system

The algorithm of definition of optimal conditions of SHPM diamond grinding (expert system) can be as: analytically we consider the contacting task of a single grain and SHPM surface and define, what conditions for the given SHPM brand will be optimal from the point of view of intensity tolerance removing. It is a grain brand (i.e. its physical-mechanical characteristic, size, orientation of grain to SHPM surface by a "hard" or "soft" plane), speed, contact pressure. Having received load for a single grain, we are set in working grain height $h_B < h_P < 2a - l_{CR}$, and having calculated a common maximum safe load, not causing cracking of polycrystal surface, we define maximum safe number of grains in contact. In accordance to assigned h_P and number of grains in contact, we assign optimal concentration in a wheel.

The special ways of diamond grinding are necessary for realization of the developed expert system.

2. WAYS OF SHPM GRINDING WITH COMBINED CONTROL OF A WHEEL CUTTING RELIEF

At the Kharkov State Polytechnic University the ways of diamond grinding with combined direction of a metal-bonded wheel cutting relief have been worked out [1,2,3,4,5].

These ways allow to realize controlled bond removing in an off-line zone (for example, by electroerosional or electrochemical ways) and to realize ultrasonic effect on tops of diamond grains, thus to control character and intensity of their microdestruction. These ways provide double effect on a working surface in an off-line zone. To guarantee constant fragile microdestruction of a diamond grain working surface and to avoid forming of grain wear platforms, the grains are treated by the means of continuous vibrational-shock dressing [6] with required intensity. For continuous and successive introduction of new diamond grains instead of worn out, in an off-line zone the electroerosional or electrochemical removing of bond with intensity, which equals intensity of decrease of grain height, is carried out. Besides, vibrational-shock influence on diamond grains is characterized by effect of deepening of the grains in the bond with intensity V_D, that helps more long-lived holding of grains on a WWS surface. On the basis of such combined direction of wheel cutting relief, we propose three ways of grinding. For all of them the ultrasonic control of developmentness of submicrorelief of diamond grains (fig.3) is proper.

The vibrational influence on the grains is carried out by the means of a plane tool – shocking tool (4) with dimensions 25x25x15, which working surface is equipped by the "tablets" (5) of a superhard material, for example by SKM-R.
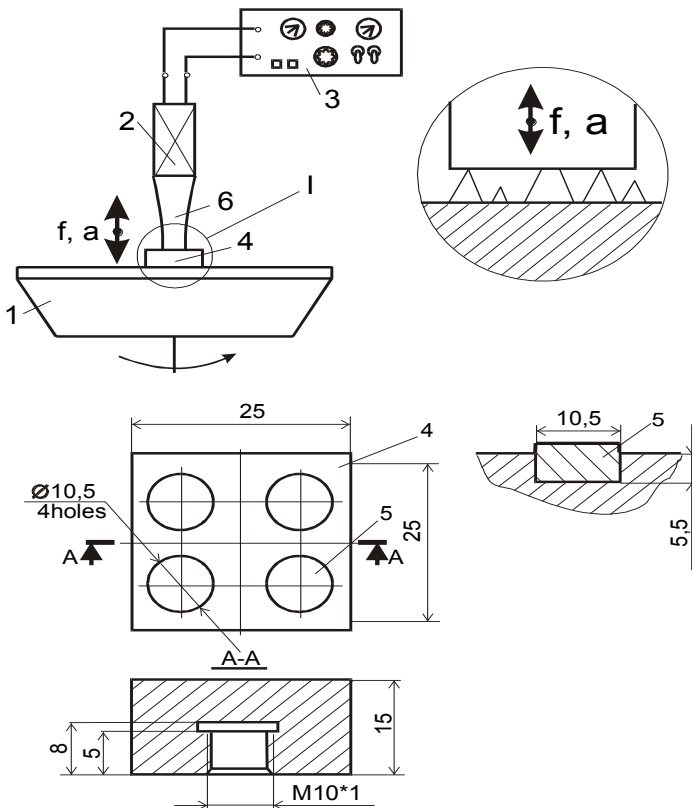
Figure 3 – The scheme of vibrational-shock influence on a wheel working surface
in an off-line zone: 1 – diamond wheel, 2 – magnetostrictive vibrator, 3 – ultrasonic
oscillator, 4 – working tool, 5 – "tablet" from SHPM, 6 – concentrator

This tool (4) is attached to the concentrator of oscillation (6) of magnetostrictive vibrator (2). The operation of the vibrator is actuated by means of the ultrasonic oscillation generator (3). The calculation of the form and dimensions of the concentrator (6) and the way of the mounting of the shocking tool is realized according to the known method [7]. An oscillation frequency f and amplitude a are defined experimentally depending on required intensity of grain microdestruction.

For SHPM processing based on nitride of boron, when the intensity of a linear wear of diamond grains is rather insignificant, and consequently the intensity of bond removing should also be corresponding, the most simple way of grinding

with vibrational-erosive control of WWS by means of the source of a direct current (fig.4b) can be applied. Electroerosive spark (bond removing) between a metal surface of the shocking tool and the bond takes place owing to the varying gap at vibrations from h_{max} up to h_{min}.
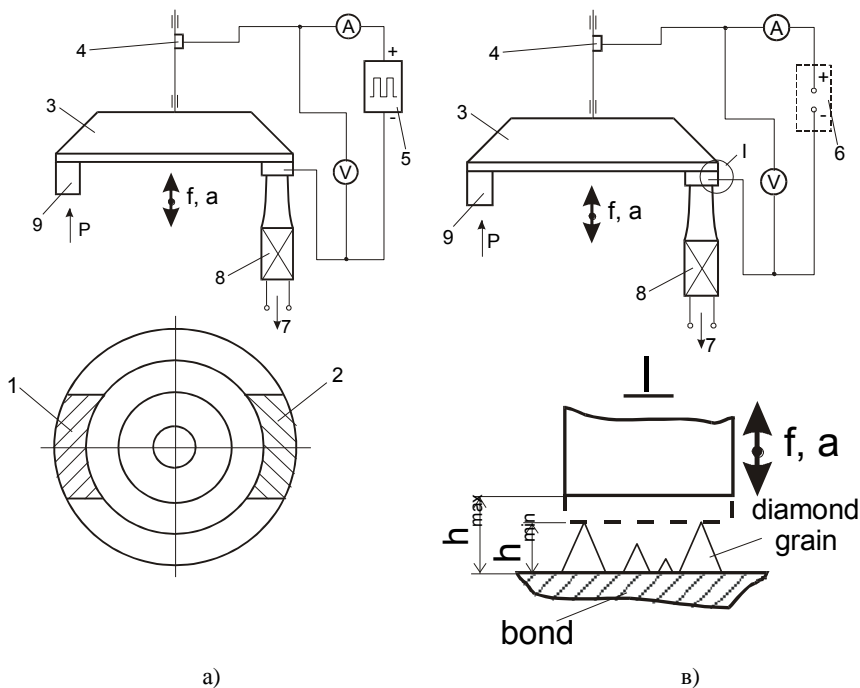

Figure 4 – The ways of grinding with vibrational-erosive control of WWS:
1 – grinding area; 2 – zone of vibrational - erosive control of WWS; 3 – diamond wheel;
4 – current-collector; 5 – pulsing oscillator ШГИ-40-440; 6 – source of a direct current;
7 – to the generator of ultrasonic oscillations; 8 – device of ultrasonic dressing;
9 – machined sample; 10 – shocking tool-electrode

During SHPM processing based on the diamond, when the intensity of a wear of diamond grains is extremely high, and consequently the same intensive directed action on the wheel bond is required, use a source of direct current is not enough. In this case pulsing oscillator ШГИ-40-440 (fig.4a) is applied to erosive control of parameters of WWS. The modes of operations of this generator are defined

experimentally, depending on required intensity of directed influence on the wheel bond.

This way has more wide opportunities in comparison with the first one, but it is more expensive.

The way of electrochemical bond dissolution in a control zone has the greatest intensity of bond removing from wheel working surface [8]. Therefore, the way of grinding with vibrational-electrochemical direction of a wheel cutting surface (fig.5) will be the most effective in case of sharpening cutters from SHPM together with steel holder, when besides removing bond, it is also required to remove waste of grinding (metal chip).

In this case there are three zones on the wheel working surface:
- grinding area;
- zone of vibrational control of diamond grain maturity;
- zone of electrochemical control of WWS maturity.

The worked out ways of grinding with combined direction of wheel cutting relief allow to stabilize the process of grinding at any level in a range from productive one up to ultra precision. These ways provide:
- directed microdestruction of tops (wear platforms) of diamond grains due to vibrative-shock influence by means of the shocking tool in an off-line zone;
- deepening of grains into the bond in an off-line zone by means of the ultrasonic shocking tool, that prolongs action period of grains on WWS;
- directed bond removing to ensure entrance of new diamond grains in exchange of worn ones and ones, dropped out from the bond, in operation.

In this case stability of grinding process, that is extremely important in automatized productions, is achieved under condition of:

$$V_B = V_1 + V_2 + V_3 \qquad (3)$$

where V_B - linear speed of bond removing; V_1 – linear grain wear intensity in a grinding area; V_2 - intensity of destruction of grains in a zone of control; V_3 - intensity of bond "ramming" in the bond in zones of direction and grinding.

Such combined ways of control of a state of wheel working surface allow to use wider potential cutting properties of diamond grains and to increase efficiency of SHPM grinding. In case of disconnect of controlling influences on wheel working surface, on diamond grains in the mass order the wear platforms will be derivated and the process is transformed practically to the process of friction "diamond - diamond" with the removal value on a nanolevel. When using precision

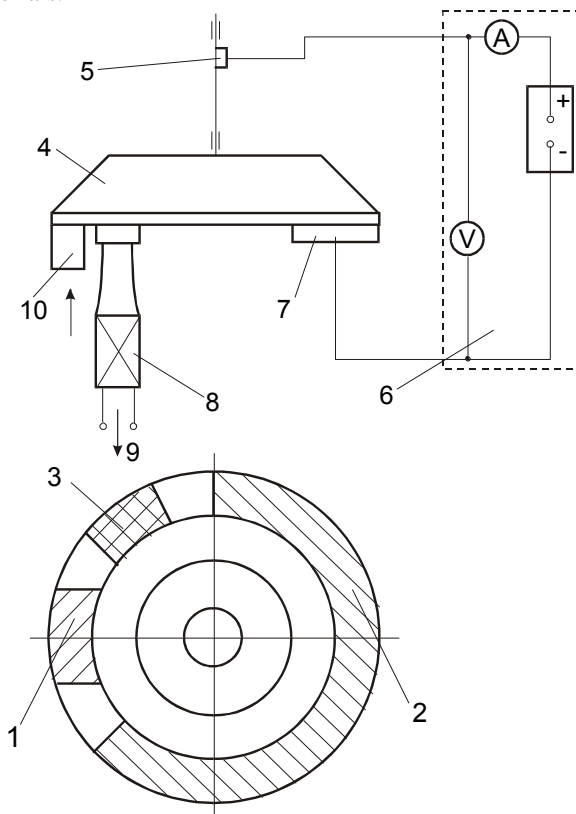equipment under these conditions it is possible to realize ultraprecision grinding of superhard materials.

Figure 5 – The way of grinding with vibrational – electrochemical direction of WWS: 1 – grinding area; 2 – zone of electrochemical direction of WWS; 3 – zone of ultrasonic direction of WWS; 4 – diamond wheel; 5 – current-collector; 6 – source of a direct current; 7 – cathode device; 8 – device of ultrasonic dressing; 9 – to the generator of ultrasonic oscillations; 10 – machined sample

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ АЛМАЗНОГО ШЛІФУВАННЯ НАДТВЕРДИХ МАТЕРІАЛІВ

Анотація. *Для реалізації запропонованої експертної системи розроблені способи шліфування з комбінованим управлінням параметрами робочої поверхні алмазних кругів. Розроблено способи алмазного шліфування надтвердих полікристалічних матеріалів з управлінням робочою поверхнею шліфувального круга на основі моделювання процесів руйнування в зоні обробки. Розроблені раніше способи шліфування з автономним управлінням ріжучим рельєфом кругів (РРК) істотно розширюють технологічні можливості алмазного шліфування. Однак недоліком цих методів, особливо при шліфуванні надтвердих полікристалічних матеріалів, є те, що при масовому виникненні на РПК площадок зносу, які стають обмежуючим фактором процесу шліфування, такі зерна примусово видаляються зі зв'язки. Такий процес істотно знижує коефіцієнт використання потенційно високих ріжучих властивостей алмазних зерен і збільшує їх питомі витрати. Отже, постає завдання управління процесом утворення площадок на зернах, тобто забезпечити їх крихке мікроруйнування з утворенням субмікрокромок. Запропоновані авторами способи передбачають подвійний вплив на робочу поверхню в автономній зоні. Для забезпечення постійного крихкого мікроруйнування робочої поверхні алмазних зерен і виключення утворення на них площадок зносу вони піддаються безперервній вібраційній правці з необхідною інтенсивністю. А для безперервного послідовного введення в роботу все нових алмазних зерен замість зношених, в автономній зоні здійснюється електроерозійне або електрохімічне видалення зв'язки з інтенсивністю, рівною інтенсивності зносу зерен. Такі комбіновані методи управління станом робочої поверхні кругів дозволяють більш повно використовувати потенційні ріжучі властивості алмазних зерен і підвищити ефективність шліфування надтвердих матеріалів. При відключенні управляючих впливів на робочу поверхню круга, на алмазних зернах в масовому порядку утворюються площадки зносу і процес трансформується практично в процес тертя «алмаз-алмаз» з величиною знімання на нанорівні. При використанні прецизійного (надточного) обладнання в цих умовах можна реалізувати ультрапрецизійне шліфування надтвердих матеріалів.*
Ключові слова: *надтверді полікристалічні матеріали; процеси руйнування; алмазне шліфування; робоча поверхня круга; комбінована схема; система "полікристал - зерно - зв'язка".*