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PROCESSING OF SUPERHARD AND BRITTLE MATERIALS AND MONOCRYSTALS IN REGIME OF QUASI-PLASTIC DEFORMATION OF THE MATERIAL BY THE METHOD OF DIMENSIONAL MICROGRINDING ON CNC MACHINE

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ABSTRACT. By theoretical and experimental researches, it has been found out that in certain conditions at mechanical action the brittle hard materials show plastic properties. It become possible the brittle materials to be processed in a way, at which the prevalent mechanism is not the destruction, but the plastic flow. The theoretical model of dimension-adjustable and non-defect processing of minerals with hard structure by cutting has been developed on the basis of the physical mesomechanics.
The physical mesomechanics of the materials is based on a new paradigm – the conception of the structural levels of the hard bodies' deformation. The regime of plastic surface processing of brittle minerals and materials could be provided at a special choice of processing parameters.

ОБРАБОТКА НА СВРЪХТВЪРДИ И КРЕХКИ МАТЕРИАЛИ В РЕЖИМ НА ПЛАСТИЧНО ДЕФОРМИРАНЕ НА МАТЕРИАЛА ПО МЕТОДА НА РАЗМЕРНОТО МИКРОШЛИФОВАНЕ НА МАШИНИ С ЦИФРОВО-ПРОГРАМНО УПРАВЛЕНИЕ

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РЕЗЮМЕ. Чрез теоретични и експериментални изследвания е установено, че в определени условия, при механично въздействие, крехките твърди материали проявяват пластични свойства. Възможно е крехките материали да бъдат обработвани така, че преобладаващият механизъм да бъде не разрушение а пластично протичане. Теоретичният модел на размерно-регулируемата и бездефектна обработка на минералите с твърда структура чрез рязане, е създаден на базата на физическата мезомеханика, в чиято основа лежи нова парадигма – концепцията за структурните нива на деформация на твърдите тела. Режим на пластична повърхностна обработка на минералите и материалите, може да бъде осигурен при специалин подбор на параметрите на обработката.

Currently, attention is paid to the establishment and development in Russia to the diamond complex, based on the use of Russian diamond resources for production of new articles for microelectronics, aircraft technologies, medicine and jewelries. Attempts have been made for solution of the problems of non-defect diamond processing, including in "hard" direction with regard to abrasion in crystal lattice. At that, the quality of the processed diamond surface is of great importance.

Due to the achievements in mesomechanics, it has become possible the brittle materials to be processed in a way, at which the prevalent mechanism is not the destruction, but the plastic flow. At such a grinding of the brittle materials in regime of plasticity, the properties of surface obtained are as after polishing or lapping.

The plasticity of brittle materials appears at small loads and movements of the processing tool. The success in electronic microscopy of deformed materials and alloys allows the fundamental regularities of the appearance of the movement and self organization of the basic type of the deformational defects – the dislocation to be researched on microscale level.

The theory of dislocations, developed on this basis allows a physical interpretation of many regularities of the hard body's behavior in different load conditions to be given.

A stage of the nature of plasticity and strength of the hard bodies of principle importance is related to the development of physical mesomechanics of the materials. Its main task is the quantitative relation of the dislocations movement on microscale level to the integral mechanical characteristics on macroscale level depending on the material composition, it internal structure and load conditions. The physical mesomechanics of the materials is based on a new paradigm – the conception of the structural levels of the hard bodies' deformation. It has been theoretically grounded and experimentally confirmed that the slip researched in microlevel as an elementary act of plastic flow is accompanied by rotational oscillations with natural frequency of the deformation on a higher mesoscopic scale level. The rotational oscillations with natural frequency involve in a self-harmonized deformation the whole hierarchy of structural levels of the loaded medium. During the plastic flow, the loaded material forms dissipative structures on mesolevel, able to realize

plastic deformation in the scheme “slip +rotation”. This way, the hard body subjected to deformation is a multilevel hierarchic self-organizing system, in which the micro-, meso- and macro-levels are interconnected.

So, the achievements in the field of physical mesomechanics have revealed new possibilities for processing of brittle materials in regime of quasi-plasticity. Apart from that, it has been found out that the appearance of the area of plastic deformations is not only related to the material nature (brittle or plastic, solid or soft, amorphous or crystal), but to the cutting depth as well. At that condition, formation of similar plastically deformed areas is observed at processing of various ceramic materials and also glasses and crystals (Коньшин А.С., Сильченко О.Б., Теплова Т.Б., 2002.).

At external action of a rhythmic field in elastic processing system (EPS) on microlevel there is an action of a grain of the cutting tool on a point of the processed surface. Oscillations of the mesovolume appear on mesolevel gradually disturbing its slide resistance. Break of the surface section happens on macrolevel (fig. 1).

On the basis of the data of hard materials grinding in plastic regime it has been find out that in order a visible brittle break to be avoided at glass grinding, the gradation of accuracy adjustment of the cutting-in feed per a rotation of the abrasive disk should not be less than 5 nm. Such a level of accuracy could has been rarely found in grinding practice because of the extremely rigid constructional connections needed in order a considerable mutual movements of the processed detail and the abrasive disk under the influence of disturbances of different types not to be allowed. The equipment PEGASUS, developed by T. G. Bifano and T. A. Dow (Bifano. T.G., Blake. P., Dow, T.A., and Scattergood, R.O. June.1988.) has been used in the task solution. The equipment design is based on the fact that grinding in regime of plasticity needs combination of high rigidity (in order precision to be provided) and small speeds of cross feed (providing the material separation in accordance with the plastic flow model (fig. 2)).

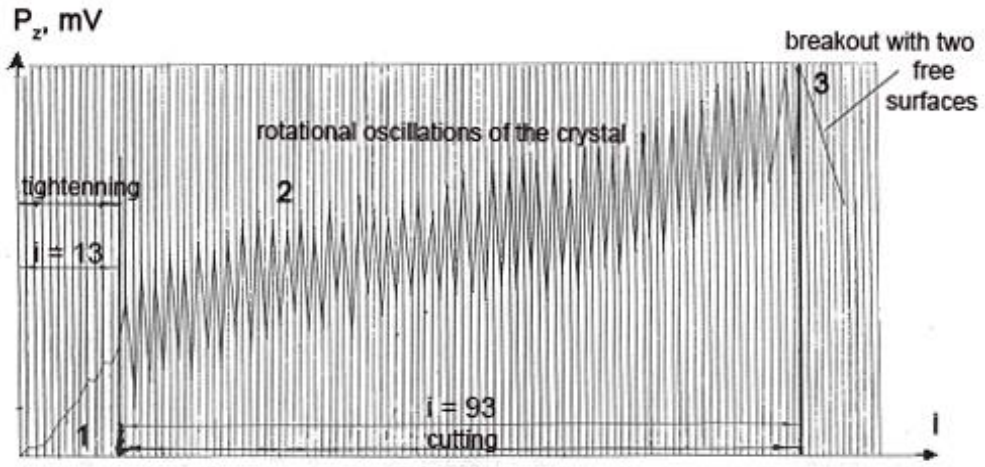

Fig. 1. Experimental oscillogram of alteration of the cutting force normal component. 1 – section of the stressing (tightening) accumulation ; 2 - section of the transient process ; 3 – section of stationary regime; P_z – normal component of the cutting force; i – number of the working paths.

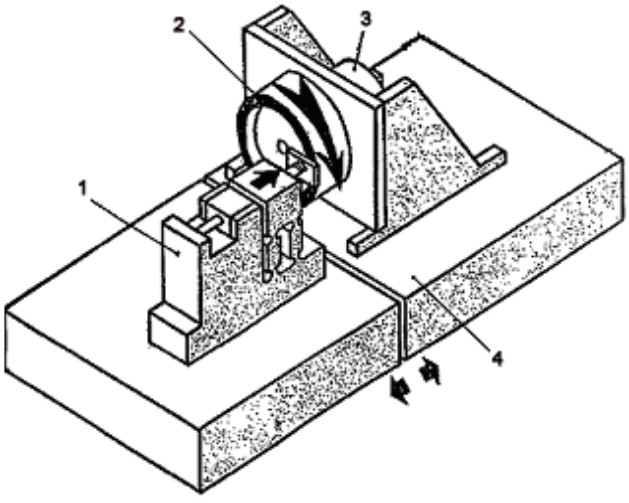

Fig. 2. Diagram of PEGASUS. 1 –work fixture; 2 – abrasive disk; 3 – spindle; 4 – dovetail slide.

This way, all the materials regardless of their hardness and brittleness during the mechanical processing, if the feed is small enough, undergo transition from brittle regime of material separation to plastic. The existence of such a transitional feed speed has been demonstrated by the abovementioned equipment in a series of experiments.

The task set has been solved and realized by special equipment.

The suggested method for dimensional plastic microgrinding of superhard and brittle materials and monocrystals is realized on a CNC machine (fig. 3) and allows products of high optical classes of cleanness at surfaces with complex profiles to be obtained.

The suggested method (Коньшин А.С., Сильченко О.Б., Брайн Джон Сноу. Патент RU 2165837 С1. - Москва, 2001г) of dimensional microgrinding of articles mainly from superhard and brittle materials becomes realizable by application of elastic processing system with certain amplitude-phase frequency characteristics of the grinding CNC machine with a tool consisting of connected cutting grains.

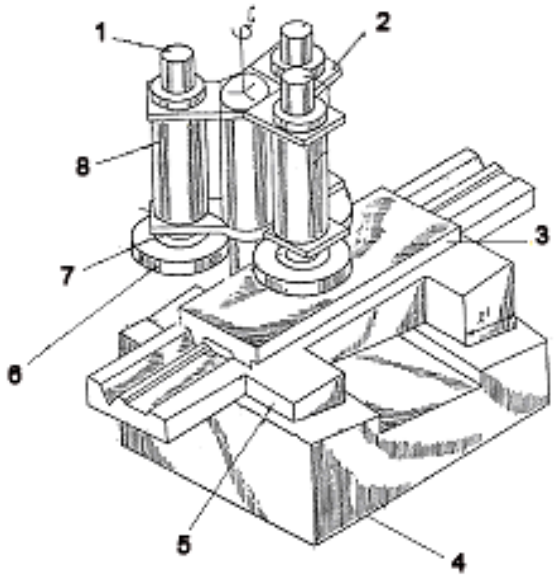

Fig. 3 Machine for dimensional microgrinding with three cutting tools.
1 – motor; 2 – cutting tool fixture; 3 – stop; 4 – frame; 5 – slide; 6- cutting tool; 7 - cutting tool fixture; 8 – drive of rotation.

The mathematical package for determination of the technological parameters includes the introduction of elasticity limit under compression, set dimensions of the finished article, set height of the microroughnesses of the processed surface of the finished article, calculation parameters of the taking down intensity. At each crossing of every indicated contact point of the processed surface and the specified point of the cutting grain the static and dynamic component of the cutting force are continuously measured and the results are used for continuous determination of the static and dynamic component of the elastic deformation of the processing system for each indicated point. During the process of the specified measurements is determined the moment of appearance of the periodically steady dynamic component of the cutting force, corresponding to the moment of the machine control system outcome to a controllable grinding regime, at which a correction is made on the smaller value of one of the parameters of the intensity of the allowance taking down, in such a way that in every indicated contact point the dynamic component of the elastic deformation of the processing system not to exceed the preset height of microroughnesses on the processed surface of the finished article and the sum of the static and dynamic components of the elastic deformations of the machine processing system not to exceed the preset limit of compression elasticity of this system.

Before grinding the machine has to be dimensionally adjusted. In order this to be done all its basing members such as processing tools and the processed articles, and the mechanisms for the executive displacements of these members toward each other are adjusted in a way allowing theoretically an article with the preset dimensions to be obtained.

The drives of coordinate movements along the axes *x, y* and *z* allow the longitudinal and cross feeds to be adjusted by the CNC system in a wide speed range on a various laws. These constructional special features allow articles with complex profile to be made such as ingenious types of facets with protruding elliptic walls.

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