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THE SHAPE OF ABRASIVE GRAIN GENERATING METHODS IN NUMERICAL ANALYSIS

The aim of this work is to present the methods of abrasive grain numerical model geometry generation based on analysis of real grain pictures. The methodology of abrasive grain shape generation, for three different images analysis methods, was presented. Obtained an irregular geometry of abrasive grains. The possibility of implementation of irregular numerical grain models into the ANSYS program, will allow to the modeling and numerical simulation of machining process at higher accuracy of numerical results (the numerical model will have reduced simplifications in relative to the real machining process). The numerical results will be subjected to experimental verification and may provide a basis for further modeling studies in this scope.

1. INTRODUCTION

Progressive technological development in the last years has contributed significantly to the creation of new methods for modeling and testing the properties of abrasive tools. Abrasive grain shape is difficult to define. It was previously simplifies the form of a sphere, rectangular prism, cone. However, many tests conducted by research centers in the country and the world lead to the conclusion: this simplification of geometry not fully reflect of phenomena occurring during grinding in practice and the results may be significantly divergent [8],[10],[11],[14]. This problem is so general and significant, that are still undertaken new work on the modeling of the abrasive grains shape geometry. During the contact with the workpiece the grain angle of attack is generally rounded, but in the case of micro-cutting when tool geometry it’s not specified angle of attack can be negative [1],[2]. Prominent peaks are replaced with abrasive grain equivalent cone or pyramid with rounded or without rounded of the top. In some cases, the abrasive grains and cutting vertices approximates to the shape of a sphere [6].

Industry puts more and more requirements for accuracy and precision manufacturing components cooperating with each other. Surface layer of these elements should have a clearly defined parameters and properties, because usage of machining process can

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remove the layers of material in order to obtain low surface roughness with very high accuracy dimensionally-shaped. Machining process requires accurate knowledge and understanding of the phenomena occurring during a single abrasive grain machining (Fig. 1).

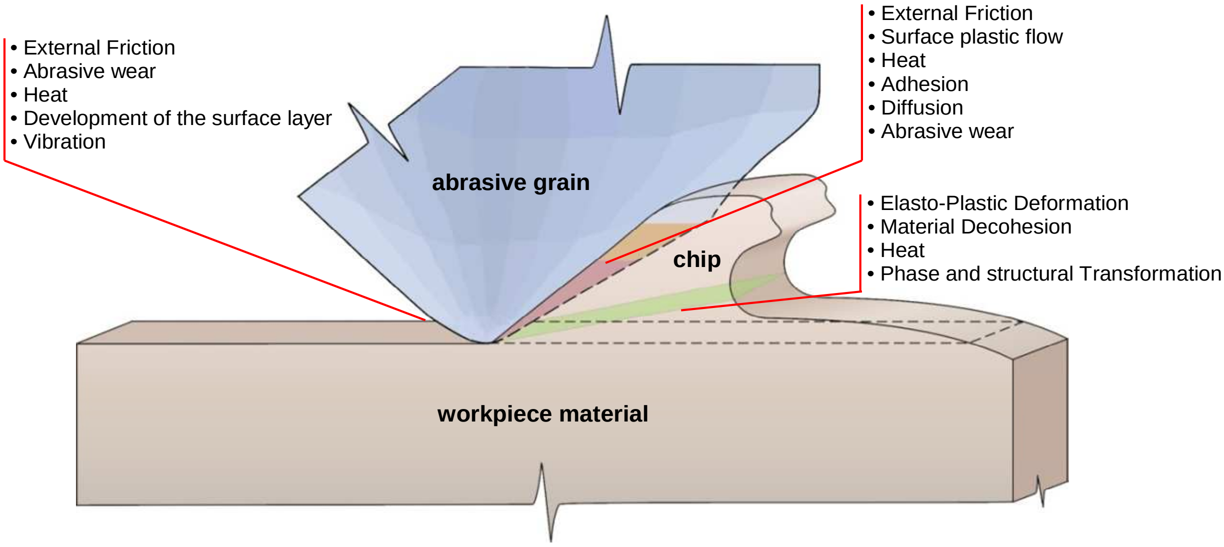

Fig. 1. Phenomena occurring during a single abrasive grain cutting

During the machining is in a state of physical mechanisms, which include: separation of the material, durability and wear of abrasive tools [3], technological quality of the surface layer, efficiency and economy of the process, etc. High costs of the process, and experimental labor intensive, as well lack of explanation of the physical mechanism of the cutting process, tend to use alternative methods which are properly programmed simulation research.

2. ABRASIVE GRAINS GEOMETRY MODELING METHODS

In previously used methods to obtain the geometry of the abrasive grain, determine the average equivalent or statistical dimension. In a series of theoretical research conducted in the country and around the world as a form of abrasive grain accepted a simplified model in the form of a sphere, pyramid or cone [9],[12],[13]. Replacing the irregular geometry of the simplified model of blunt edges solid leads to significant differences in the course of physical phenomena accompanying the process of machining and therefore into difference in predicting quality technological product. A significant difference in the approach proposed by the author is possibly true reproduction of geometry of the grain [7]. The proposed new method of grain shape generation will be based on an analysis actual image abrasive grain and create its numerical reproduction. Possibility of implementing numerical and irregular models of abrasive grains to the Ansys program will allow for modeling and numerical simulation of abrasive processes with a higher accuracy of calculation results. An application developed in the ANSYS/LS-DYNA enables an explanation of physical phenomena occurring in the workpiece during of cutting process [1].

Geometrical measurements of abrasive grain were made using a measuring microscope biaxial Vision Engineering (Fig. 2a). On microscope were tested silicon carbide grains SiC (Fig. 2c). Abrasive grain was placed on the upper part of the shaft, in its axis of symmetry (Fig. 2b). Shaft placed on piles under a microscope so that it was possible its rotation along the axis of symmetry. Then performed photo abrasive grain contour, turning it by 180° with 5° intervals.

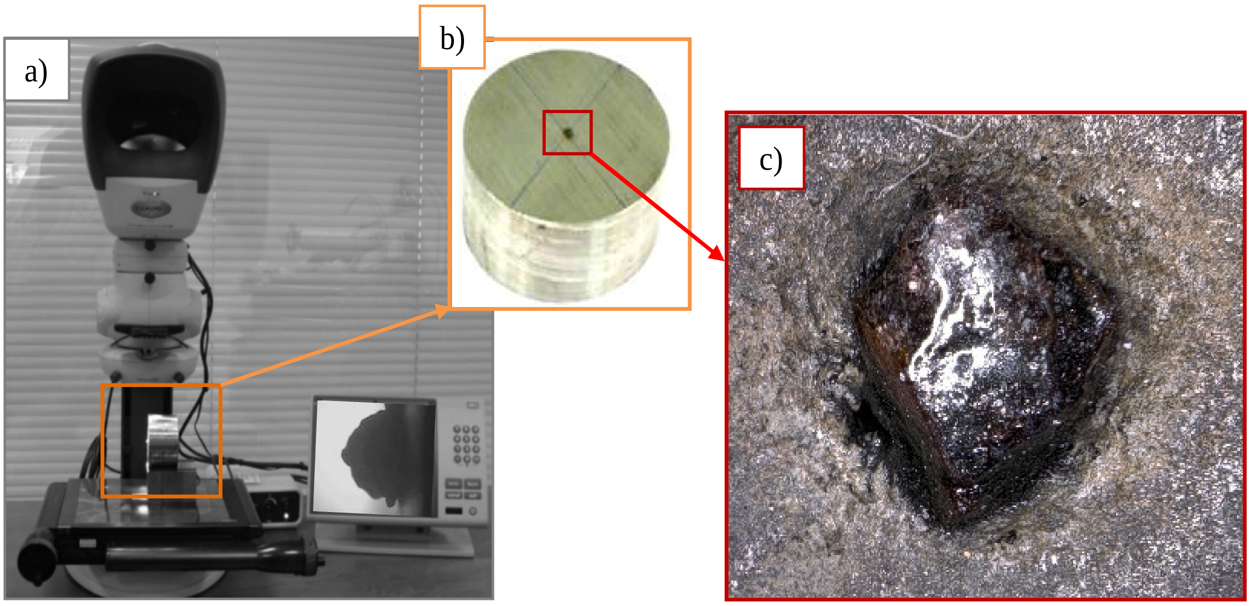

Fig. 2. Vision Engineering optical microscope

Pictures were converted to monochromatic format, and then loaded into developed in Matlab applications [4],[5]. First, the application marked the border of the light-shadow and write down the location of points located on this border in the Cartesian coordinate system. The next step was to designate the top of abrasive grain, and then the actual interpolation curves radially from the top of the grain using the user-selected number of lines (Fig. 3).

Numerical tests were carried out on the basis of copyright three methods of generating abrasive grain shape. The first method is based on dividing the radius of on equal lengths (Fig. 4). The second method is based on a "complete review" of all possible configurations of placement the start and end points of line segments and then selecting a configuration in which is the smallest sum of the lengths squares between real points, and the interpolation segments (Fig. 5). Method 3 consists in the progressive addition of subsequent points. For each point also "a complete review" solutions was made (Fig. 6).

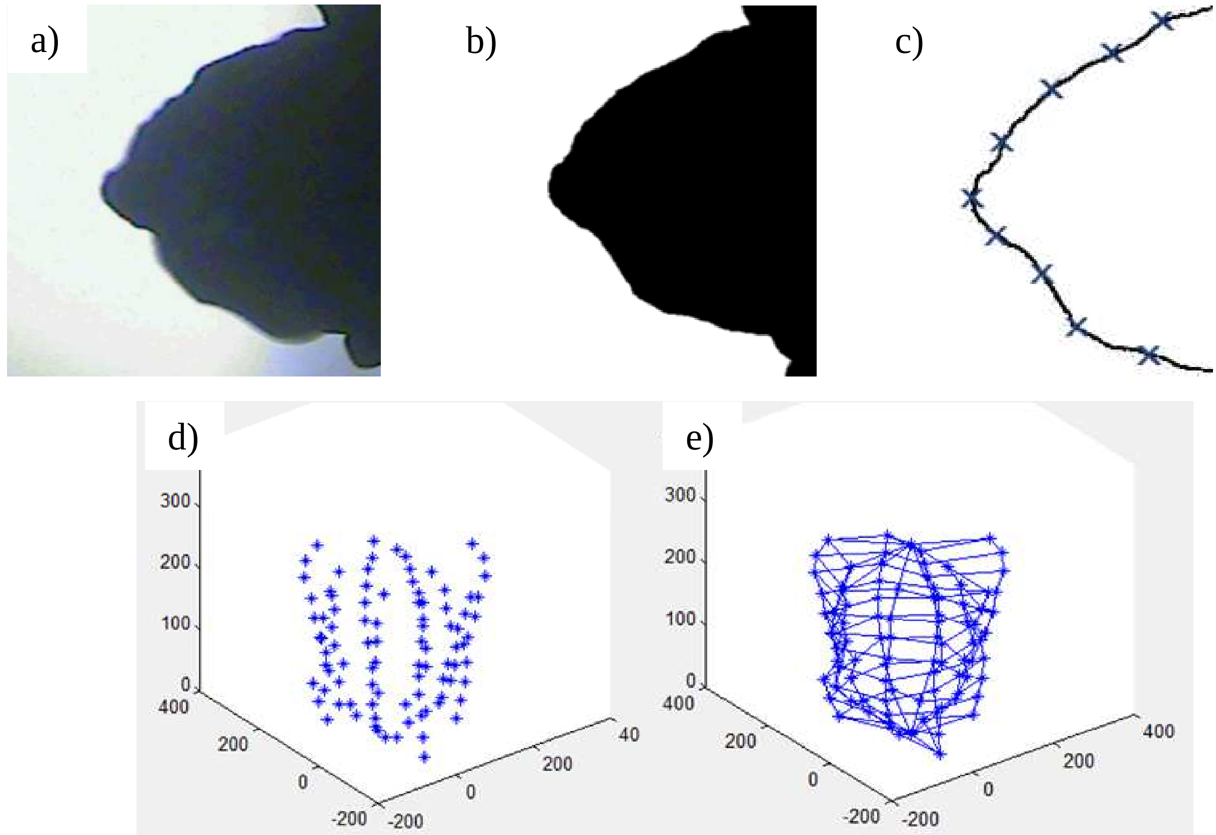

Fig. 3. Stages of generating a model of abrasive grains: a) 2D photo, b) half of the grain, c) interpolation, d) generated points, e) the combined points

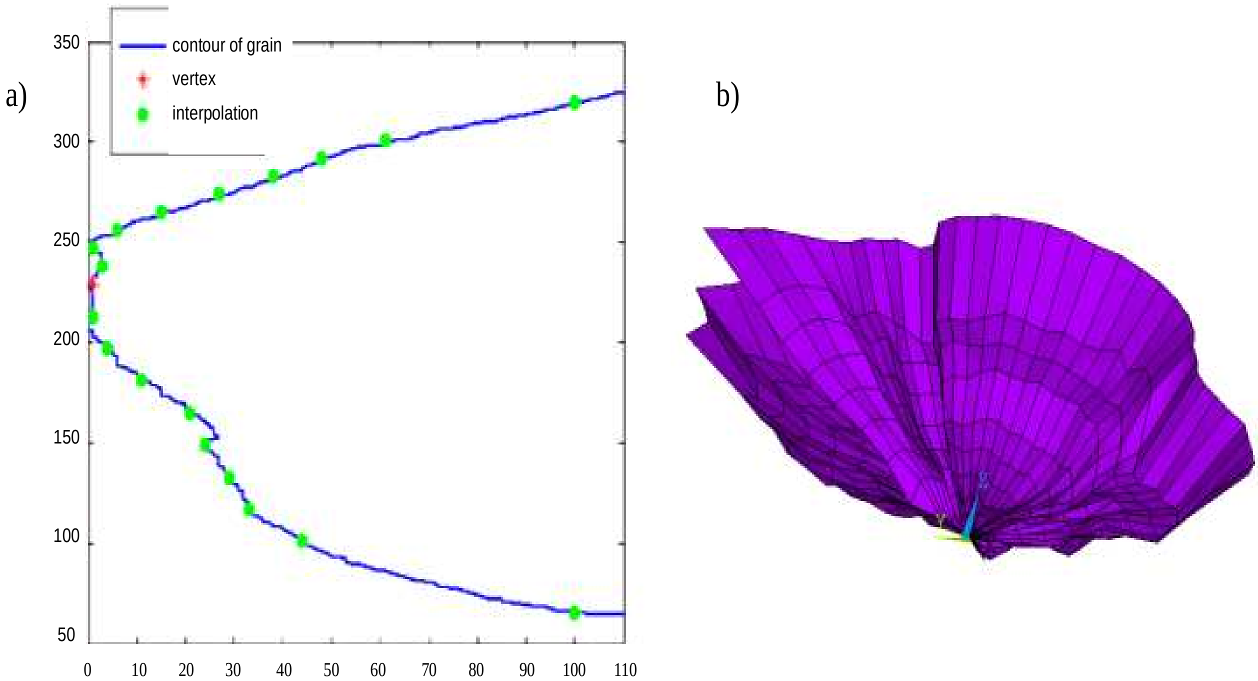

Fig. 4. First method of generating grain: a) interpolation, b) obtained geometry

a) b)

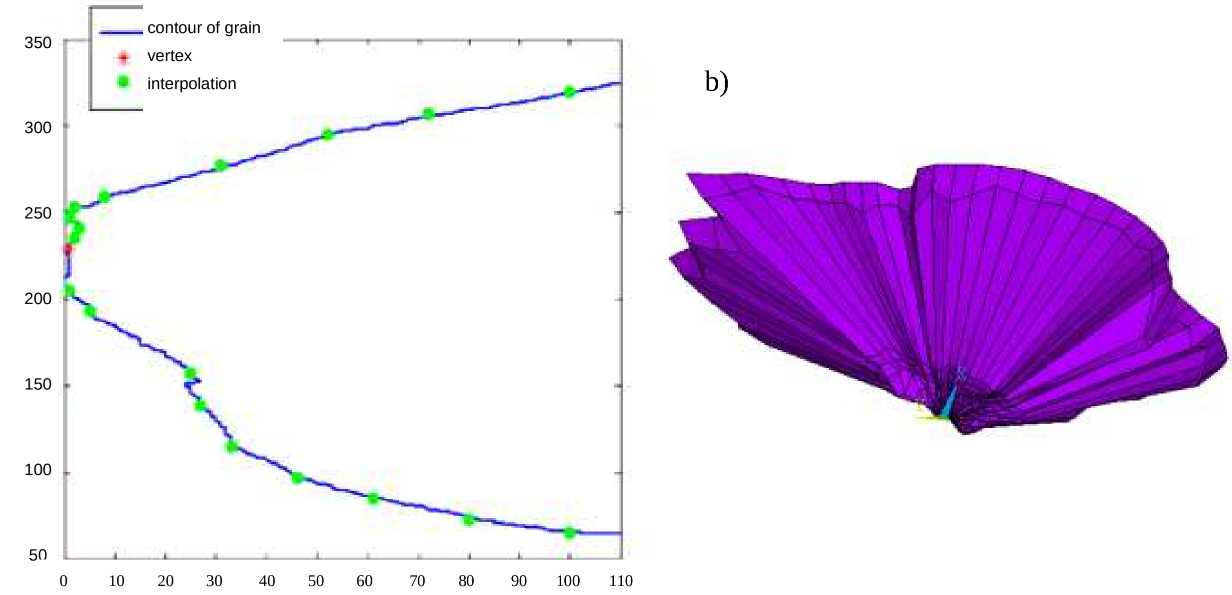

Fig. 5. Second method of generating grain: a) interpolation, b) obtained geometry

a) b)

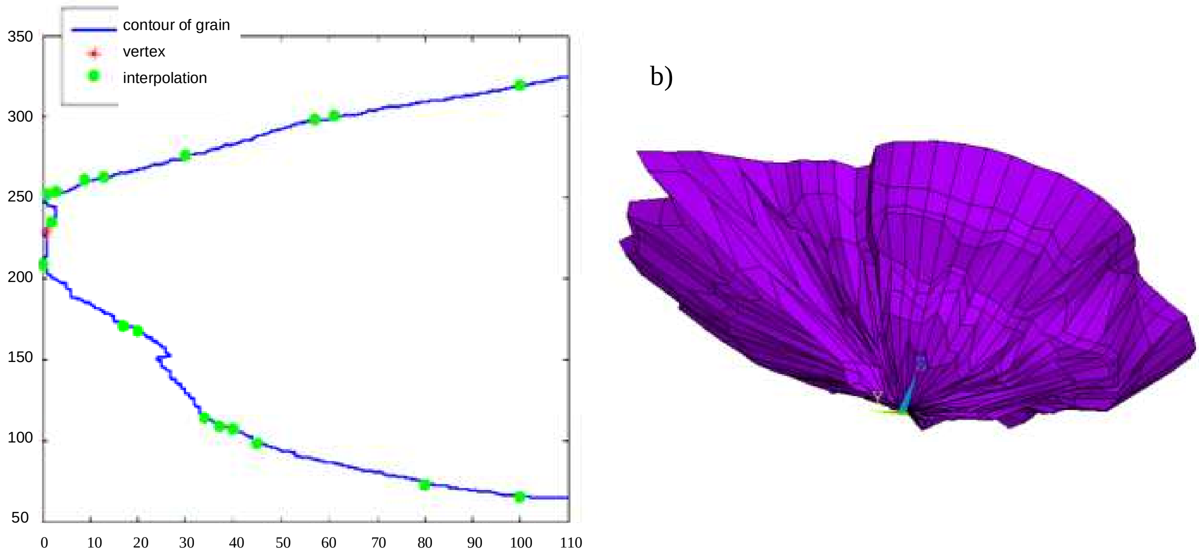

Fig. 6. Third method of generating grain: a) interpolation, b) obtained geometry

3. APPLICATION OF GENERATED ABRASIVE GRAIN

After designation location of all throws grain points for pictures, the application automatically generates program code in APDL language allows the import of abrasive grain geometry to the ANSYS/LS-Dyna program (Fig. 7). This makes it possible conduct numerical simulations of the process of cutting a single abrasive grain with an irregular geometry similar to the actual geometry of the abrasive grains [7].

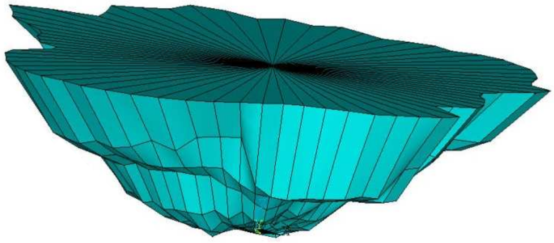

Fig. 7. Abrasive grain generated in Ansys program

a) b)

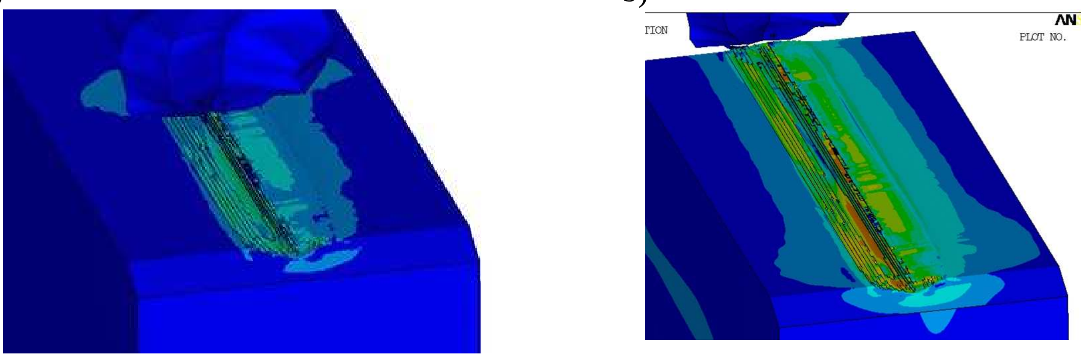

Fig. 8. Cutting with abrasive grains generated in Ansys using first method: a) the initial phase, b) the final phase

a) b)

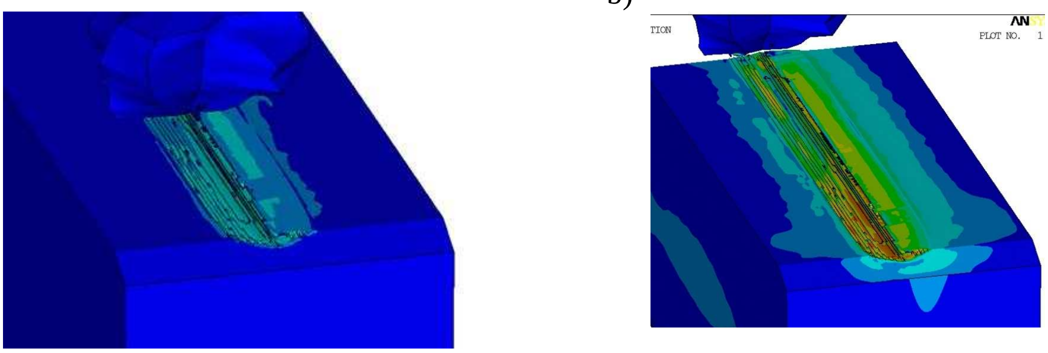

Fig. 9. Cutting with abrasive grains generated in Ansys using second method: a) the initial phase, b) the final phase

a) b)

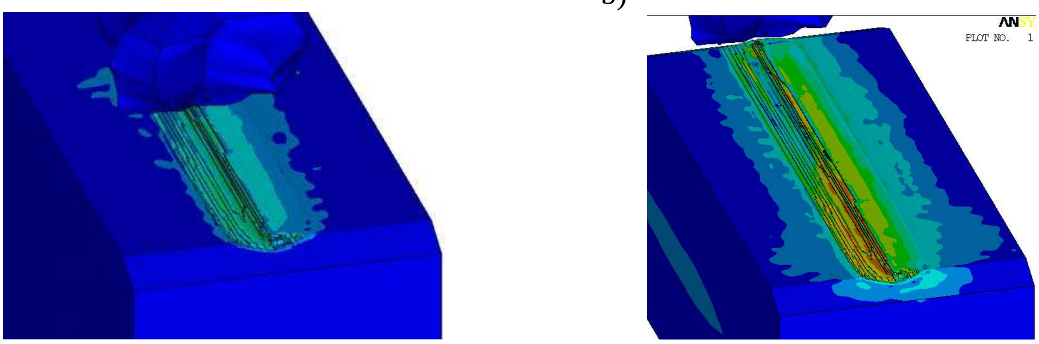

Fig. 10. Cutting with abrasive grains generated in Ansys using third method: a) the initial phase, b) the final phase

Simulations of cutting conducted with using of generated abrasive grain (Fig. 8,9,10). The simulation assumed that the particles are not deformable bodies, but treated material will tend to be deformed. The recess in the material of the abrasive grains causes an increase forces and stresses which affect the plastic deformation of the material around of all contact surfaces of grain and material. This creates furrows, side bead and upsetting of material before surface of the contact. The mechanical energy supplied to the zone of impact of the abrasive grains is used to overcome the frictional resistance, crushing, shearing and cutting of the workpiece.

4. CONCLUSION

Computer modeling and simulation of the cutting process a single abrasive grain, allows analyzing the physical phenomena whose observation or measurement is very expensive or even impossible, for example: slides, adhesion and friction in the grain-object contact zone. Modeling and computer simulation make it much easier to optimize grinding wheels and selection of appropriate conditions for implementation of a process.

Introduce methods to generate more precisely represent the abrasive grain the real geometry. This allows for more accurate reproduction of the phenomena occurring in the process of cutting a single abrasive grain. Consequently the results of using these methods to generate particles are more precise.

Using this method, the numerical simulation will save you time and money, and exclude the use of machines and additional personnel for research.

LITERATURE

[1] OLSZAK W., 2008, *Machining process*, WNT, Warsaw, (in Polish).
[2] BORKOWSKI J., 1979, *The basis application of monocrystalline abrasive grains of silicon carbide in machining*, WSInż., Koszalin, 6, (in Polish).
[3] BORKOWSKI J., 1983, *The elementary phenomena of usage of grains and abrasive tools*, WSInż., Koszalin, 16, (in Polish).
[4] KUKIELKA L., SZCZEPANSKA M., CHODOR J., 2009, *Discretized modelling and numerical analysis of machining process with single abrasive grain using finite element method*, IBM, Radom, 110 – 119, (in Polish).
[5] KUKIELKA L., BARTOSIK P., FORYSIEWICZ M., CHODOR J., 2011, *Stereometry numerical modelling of abrasive grains on the basis of their actual images*, Machining- contemporary the problems, PAK – Measurement Automation and Monitoring, Warszawa, 171-176, (in Polish).
[6] WOŹNIAK K., 1982, *Abrasive materials– production and properties* ,WNT, Warszawa, 237-247, (in Polish).
[7] KLEIBERK. J., 1982, *Finite element method in nonlinear continuum mechanics*, Library of Mechanics Applied, Institute of Fundamental Technological Research, Polish Academy of Science, PWN, Warszawa, (in Polish).
[8] JAIN V. K., I KUMAR R., DIXIT P. M., SIDPARA A., 2008, *Investigations into abrasive flow finishing of complex workpieces using FEM*, Wear 267, 71–80.
[9] ANDERSON D., WARKENTIN A., BAUER R., 2012, *Comparison of spherical and truncated cone geometries for single abrasive-grain cutting*, Journal of Materials Processing Technology, 212, 1946– 1953.
[10] DOMAN D. A., WARKENTIN A., BAUER R., 2008, *Finite element modeling approaches in grinding*, International Journal of Machine Tools & Manufacture, 49, 109–116.
[11] ANDERSONN D., WARKENTIN A., BAUER R., 2011, *Experimental and numerical investigations of single abrasive-grain cutting*, International Journal of Machine Tools & Manufacture,51, 898–910.

[12] FANG L., LI B., ZHAO J., SUN K., 2009, *Computer simulation of the two-body abrasion process modeling the particle as a paraboloid of revolution*, Journal of Materials Processing Technology, 209, 6124–6133.
[13] LI X., GRONG Y., 2011, *Framework of grinding process modeling and simulation based on microscopic interaction analysis,* Robotics and Computer-Integrated Manufacturing, 27, 471–478.
[14] AURICH J.C., KIRSCH B., 2012, *Kinematic simulation of high-performance grinding for analysis of chip parameters of single grains*, CIRP Journal of Manufacturing Science and Technology, 5/3, 164–174.