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NUMERICAL MODEL OF MATERIAL – A CONCEPT OF FEM SIMULATION USING NEURON NETWORKS

The paper presents new conceptions of numerical models of materials used for simulations of a process of grinding. Conceptions presented by authors are alternative for already existing computational solutions by finite elements method and are sources to determine new theoretical basis for their own solutions of computational systems connected with deformation of a material. The 'aiFEM' conception presented in the paper is based on elastic artificial neuron nets. Presented conceptions of numerical models material were used for simulations of a grinding process. One of conceptions presented in the article is based on a grain to the limit of a real material from which grain is made and a process of absorbing energy through a surface of a grain affecting on the material.

1. INTRODUCTION

The article presents new concepts of numerical models of materials, used for the simulation of grinding process. The concepts presented by the authors are an alternative to the already existing numerical solutions with the finite elements method and are the source for determination of new theoretical bases for own solutions of computational system connected with deformation of the material. The "aiFEM" concept presented in the article is based on flexible artificial neuron networks.

The presented concepts of numerical models of materials were used for the simulation of grinding process. One of the concepts presented in the article is based on a grain hardened to the limits of real material which the grain is made of, and the subject of numerical analysis is the process of absorbing energy by the surfaces of the grain acting upon the material. The numerical model of the material and the grain was based on a flexible neuron network with the assumption of constant distances between the neurons.

The models were developed on the basis of examination of action of a single machining grain, FEM analysis in Ansys system, and the system of simulation of grinding process developed by the authors.

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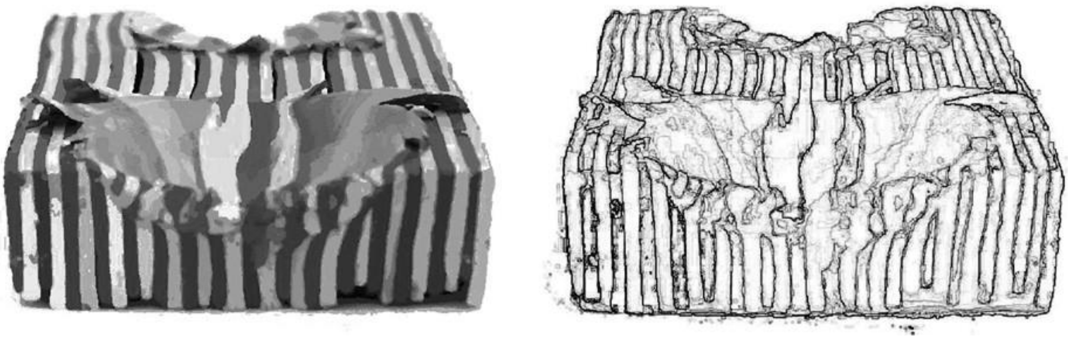
The research methods applied at the construction of the concept of the aiFEM system, apart from the analysis of work of a single machining grain, also included application of modern measurement systems. Real-life measurements allowed for digitalization of the machining surface processed with a single machining grain, and the obtained three-dimensional image made spatial dimensioning of the surface parameters possible, which in turn allowed for a better relation of the numerical process to the reality [3,4,5].

2. PROBLEM ANALYSIS

A traditional FEM system is based on the obtaining approximated solutions of boundary problems. Systems with infinite number of freedom degrees (real object) are replaced with systems with finite number of freedom degrees. Determination of appropriate discrete systems of real models is always preceded by the construction of mathematical models of the discussed phenomenon, describing individual boundary problems, and therefore analogical assumptions were used for the construction of the new model.

While designing the new aiFEM concept, preliminary analyses of deformation of the "substitute" material in macroscopic conditions were prepared (Fig. 1), and macroscopic examination (Fig. 5). The analyses of the results of the tests were compared with the simulation of deformation in the ANSYS system, and the parameters of the artificial neuron network, being the basis of the aiFEM system, were selected on the basis of the determined correlation.



a) b)

Fig. 1. Macroscopic examination of material deformation a) picture of a sample subjected to a macro-grain b) image of the sample subjected to picture enhancing in order to delimit the contour

Macro-deformations were made on samples of easily deformed material whose structure properties allowed to created a layered alloy.

Simulation research in the ANSYS system was carried out with the application of real-life grinding conditions determined on the basis of conditions in which the experimental research was carried out. The process of contact of the grain with the material was developed in the ANSYS system on the basis of a mathematical model of machining which was an additive combination of partial models (material model – thermodynamic plasticizing tension, increment of tension and deformation tensor, increment of translation tensor; dynamic movement equation; identity conditions).

In the simulation a material resilient/viscous-plastic with isotropic strengthening model was used (Cowper-Symonds Model), and the plasticizing tension was described with the following equation:

$$\sigma_Y = \left[1 + \left(\frac{\dot{\varepsilon}}{S}\right)^{\frac{1}{K}}\right] \cdot \left(\sigma_0 + \beta \cdot E_K \cdot \varepsilon_K^{eff}\right) \tag{1}$$

Where:

σ_Y – plasticizing tension (flow stress in tension) ;

σ_0 – initial values of plasticizing tension;

$\dot{\varepsilon}$ – deformation velocity (strain rate);

S and K – parameters dependent on the deformation velocity;

ε_K^{eff} – intensity of deformation (plastic strain);

$E_K = E_{tan}E / E - E_{tan}$ – plastic reinforcement module (modulus).

Explicit integration method, also called central difference method, was used for the analysis of the problem. The geometry of the sample was discretized to 8840 finite elements, and a finite solid 164 type (8-nodes) element with linear shape functions of 6 degrees of freedom (Fig. 2.) was used.

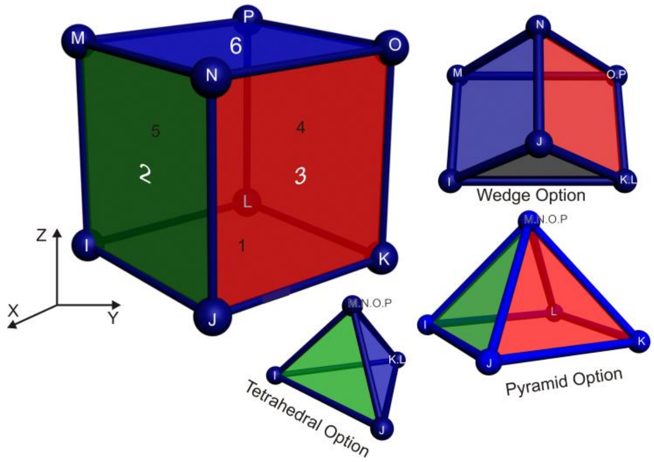


Fig. 2. Research Finite element SOLID 164 type

The velocity of machining by a grain was established at 30m/s, and the material subject to the machining was tool steel (Fig. 3; Fig. 4). The simulation of the machining process by a single grain was carried out in a module using FEM–Ansys/LsDyna. The results of the simulation presented in Fig. 3, 4 allowed to determine the initial assumptions for the aiFEM system.

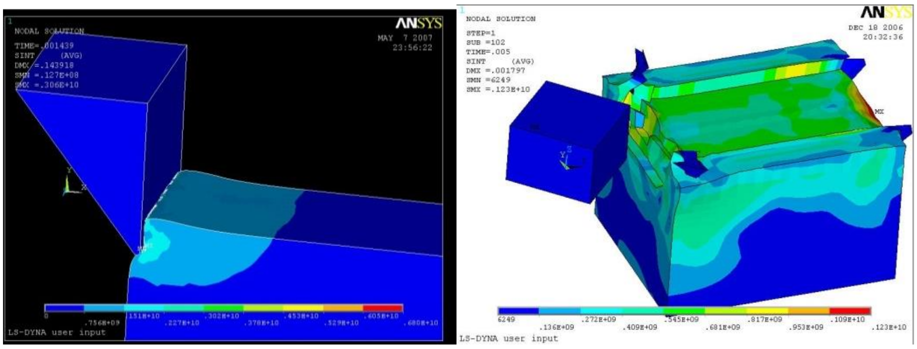


Fig. 3. Analysis of deformation in steel tool using the ANSYS system

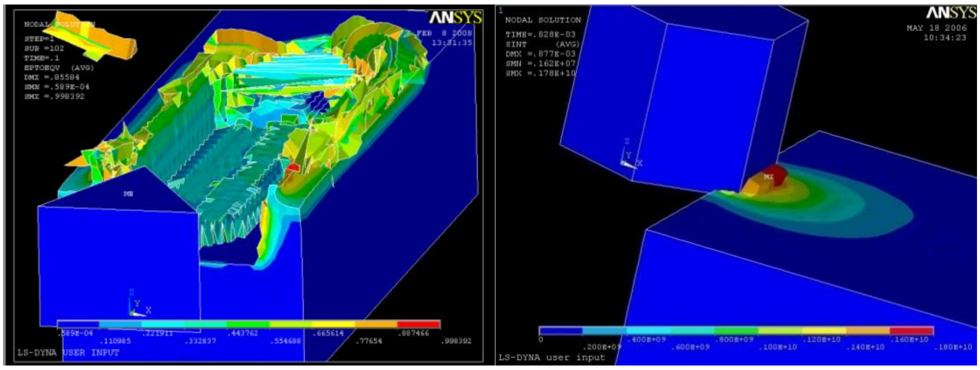


Fig. 4. Initial contact of the grain with the material

3. VERIFICATION OF NUMERICAL SIMULATIONS

Experimental verification of the assumptions for the system was carried out by means of analyses of results obtained by machining tool steel with a single grain. The machining process was carried out with the kinematic assumptions identical to those in the ANSYS

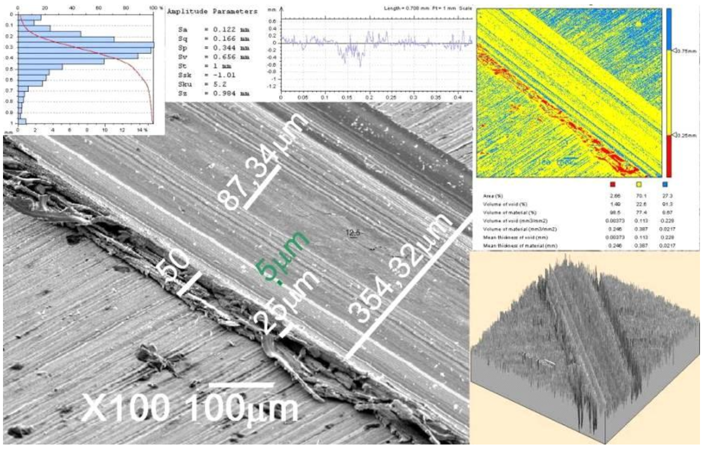


Fig. 5. Analysis of a single grain track along the grinding zone

system. State-of-the-art measurement apparatus [1,2] was used in the analyses of the effects of machining with a single grain, and the digitalization of measurements of the examined surface was carried out by means of appropriate connecting of measurement point. The procedure used cartographic methods which allowed to illustrate the results as a digital contour map.

4. THE CONCEPT OF AIFEM

Comparing the analyses of operation of a grain in the grinding zone (Fig. 5) with the analyses of simulation process carried out in the ANSYS program (Fig. 3, Fig. 4) and macroscopic examination of substitute models (Fig. 1), a new concept of analysis system for deformation of material during grinding was proposed.

Two initial models of the system (Fig. 4.1, Fig. 4.2) of grain operation in the grinding zone were proposed.

The first of them (Fig. 4.1) allows to determine the energy absorbed by the material during grinding, while the second model determines instantaneous values of the energy absorbed by the cutting edge.

The assumption was that the material behaviour during machining will be a multiplication of elementary components whose basic features are as follows:

$$m_e \cdot m_e \cdot m_e \tag{2}$$

Expression (2) specifies the size of the basic solid which is non-deformable, and the bindings of m_e solids of initial length equal d_{me} were set on flexible neuron networks.

$$\max(d_{me}(t)) = (d_{me} \cdot m_e)^c \tag{3}$$

where: c - machining constant determined experimentally

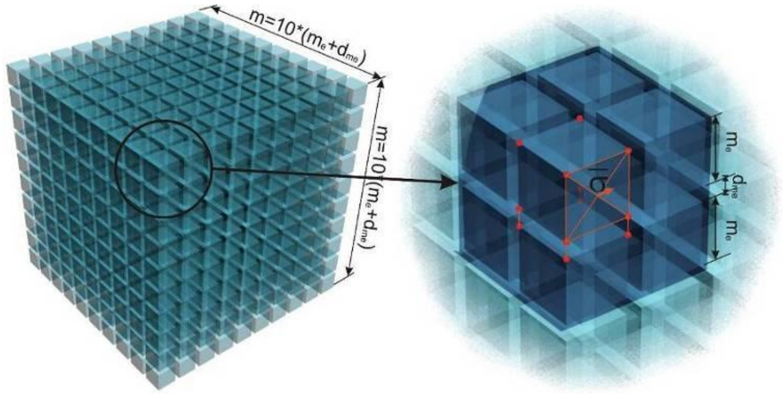


Fig. 4.1. Elementary structure of the material during machining

At the contact with the grain, displacement of elementary solids will take place up to the resistance threshold of their boundary bindings which are determined in the weights of neurons constituting the flexible network. The progressing accumulation of loads in the nodes of the flexible network will be the most important information obtained from the system. Exceeding the boundary values in the nodes of the network will result in adhesion and plastic deformation of the material. In this method, the machined material is subject to numerical analysis, and the grain is a non-deformable solid. The method allows to determine instantaneous values of the tension stresses developing on the surface of the ground material during machining.

The second model is based on a grain hardened to the limits of the real material which the grains are made of, and the subject of analysis is the process of absorbing energy by the surfaces of the grain. The numerical model of the material and the grain was based on a flexible neuron network with the assumption of constant distances between the neurons (W(n)).

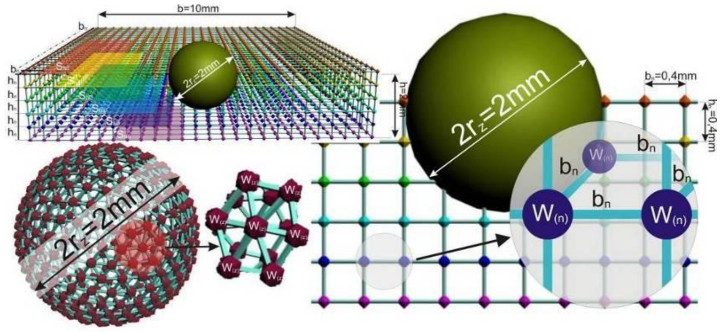


Fig. 4.2. Visualization of assumption for work with a single grain

The second model, presented in Fig. 4.2, allows to determine instantaneous energy created by the machining grain at consecutive contacts with the material. The construction of the material allows for statistical analysis of passage of the grain along the material, and the accumulated values (W(n)) allow to determine the correlations of the phenomena taking place during the grinding process. The structure of the grain in this method, due to the additive character of the contact, allows to determine the total work of grain in its period of effective machining. Accurate analyses of the data collected after the machining are possible due to the collection of instantaneous values in neurons (W(n)) [6,7].

Preliminary examinations of the presented models were carried out for a typical conditions of peripheral dry grinding of planes in a single passage for the grinding velocity of V_S = 30m/s.

The analysis of the results enabled determining of correlation between the cross-section area of the layer machined with a single grain and the value of the normal component of force for a single grain, and additionally, it was determined for which parameters of exponent n_1 the results of simulation are the closest to the results of laboratory research, which gives a basis for determination of the value of empirical coefficient C for the given material subjected to machining.

$$F_n = C \cdot A^{n_1} \tag{4}$$

Where: C – empirical coefficient specifying the type of material,

A - cross-section area of the machined layer,

n_1 – exponent.

Comparison of simulation results with experimental results allowed to determine exponent n_1 in formula (4) for the prescribed material at the level of 0.7. The value indicates comparable trends in the charts of component values of grinding forces measured experimentally and determined numerically [8].

5. SUMMARY

Carrying out a simulation of the grinding process with various methods and comparison with laboratory experiments allowed the authors to find a new approach to the analysis of deformation of material during its machining. Theoretical bases of the machining simulation system, with further development and modifications, will let, in the near future, to present a new concept of determination of tension states and deformation tensors for a material at selected initial conditions of machining process. The authors are aware that the problem they undertook to solve is very complex and difficult for experimental verification, however, due to dynamic development of IT and new engineering technologies appearing, they hope to reach satisfactory results of their research.

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