Complex Model of Surface Grinding

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Abstract — **In article the complex model of flat grinding is considered. The model allows to simulate any technological situation and to predict the major output parameters of process: a roughness of a detail, presence of defects and accuracy of processing. The structure of complex model is shown. All basic parts of model are shortly considered.**

Index Terms — **grinding, mathematics modeling, complex of programs.**

I. INTRODUCTION

Grinding is used for precision surface finishing of parts in different areas of engineering: automotive, engine building, machine tools, robotics, aircraft industry, space industry and other.

The most important output parameters of the process are:

– roughness of the finished part – the relief of micro-irregularities;

– the quality of surface finish – no burn marks, cracks and other defects;

– accuracy of processing – getting the size of parts within dimensional tolerance.

For each parameters determination, there are many mathematical models, which are presented in the form of formulas, graphs, nomograms, algorithms and programs.

The greatest interest is represented by models-programs as they work on computers which intensively develop, hence, and complexity of models can increase.

A major shortcoming of existing models-programs is that each model considers the specific area of grinding with a specific statement of the problem.

We introduce the concept of "complex model of process" - a set of models-programs describing a certain process taking into account all its features and interrelations

In this work we completely to transfer grinding process to the virtual environment, as a result, it has allowed to make computer experiments for definition of all target parameters of process without expenses.

II. THE STRUCTURE OF THE COMPLEX MODEL

The structure of complex model is presented in Figure 1.

The complex model consists of three basic models and the several auxiliary. The basic models are responsible for reception of results – output parameters of grinding (roughness, quality and accuracy). Auxiliary models allow to approach the simulated process to the real.

Functioning of complex model is carried out in the following sequence:

1. creation of the necessary quantity of abrasive grains with various sizes;
2. abrasive grains fill volume of a grinding wheel, forming thereby a working surface of the tool;
3. the material of part on its physical properties is modeled;
4. The stain of contact of a grinding circle and workpiece is modeled;
5. Mechanical (geometrical) interaction of each grain with a detail surface is modeled, the roughness is formed;
6. On volumes cut off by each grain threw-la the temperature allocated at cutting pays off, the temperature field of preparation is formed, the estimation on presence of defects becomes;
7. The effort to each grain, and a radial component of force of cutting is modeled.

Consider each module more in detail.

III. MODEL OF ABRASIVE GRAIN

Various approaches to approximating the shape of abrasive grains are exist: sphere, paraboloid of revolution, the truncated pyramid, the truncated cone, etc.

The maximum approximation to the actual shape of the approximated profile is provided by using a paraboloid of revolution.

However, the mathematical description of the paraboloid is more complicated than the description of the sphere.

So our task, which we assume the formation of surface from cutting of several tens of thousands of abrasive grains, we choose the approximation of the sphere.

The structure of each of the grinding wheel consists of 40-45% of the grains of the main fraction, and 55-60% of grains with the corresponding deviations. Therefore, the diameter of abrasive grains (b) has a normal distribution $N(b, \mu, \sigma)$ (1) [1].

IV. MODEL OF THE GRINDING WHEEL

Locations of abrasive grains in grinding wheels are random. It occurs on the stage of the manufacturing of wheel.

Mixing grains and binder operating until reception a homogeneous mass, in which abrasive grains are uniformly distributed.

Therefore, the distribution of the coordinates of the centers of grains on the working surface of the grinding wheel is made by law a uniform distribution (2).

After that generated coordinates of the centers of the grains are exposed to the statistical analysis. On this basis it is concluded on the adequacy of the distribution of the grains [1].

V. MODEL OF WORKPIECE MATERIAL

In the process of grinding rate of deformation of the material is 10^{-6}–10^{-7} sec, which is two orders of magnitude higher strain rate of standard mechanical tests, and cutting takes place in a heated metal. Therefore, to estimate the actual resistance of the material to plastic deformation is

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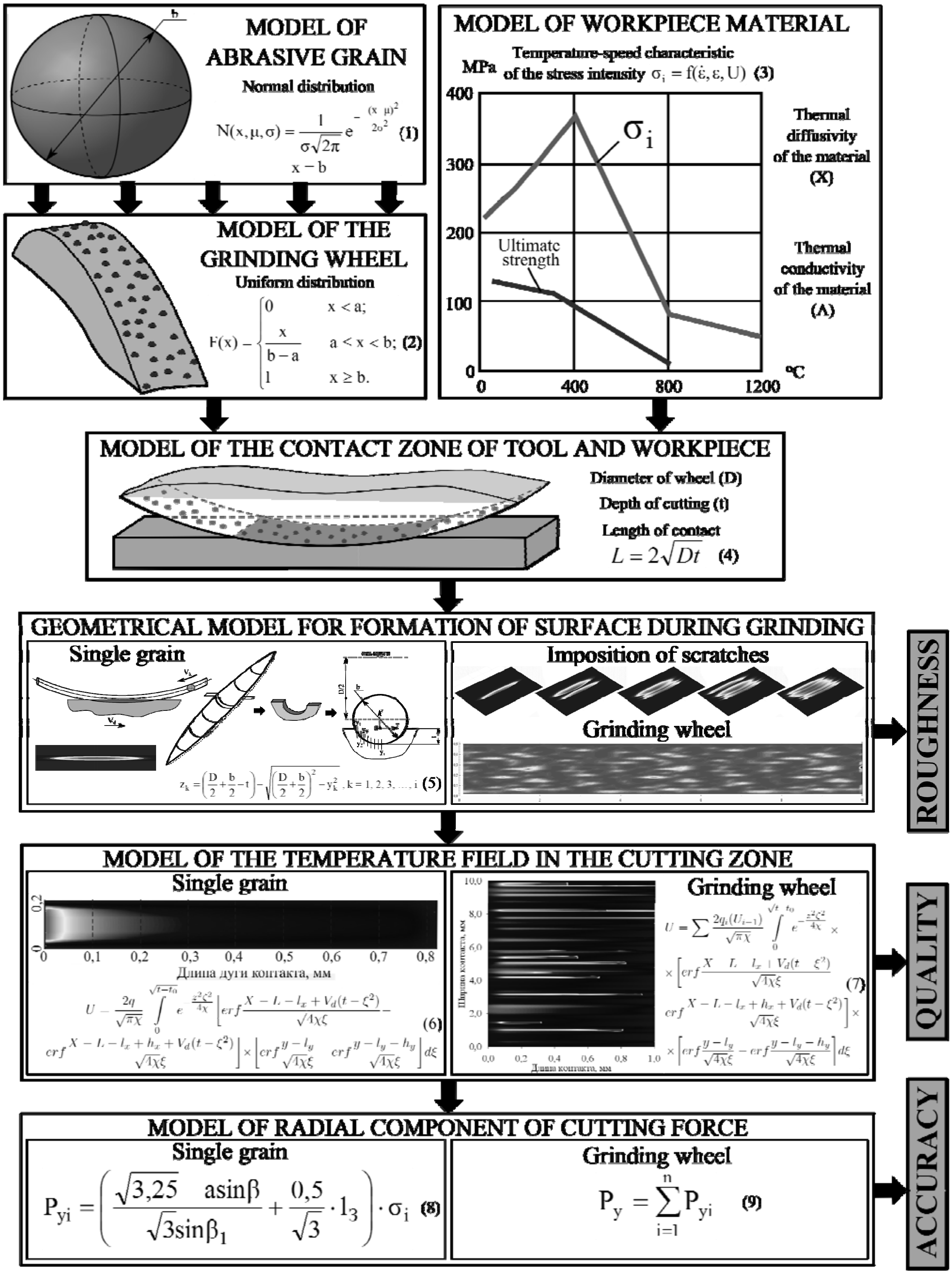

Fig. 1. The structure of the complex model

necessary to know the temperature-speed characteristics of the stress intensity the function (3):

$\sigma_i = f(\dot{\varepsilon}, \varepsilon, U)$

where $\dot{\varepsilon}$ – the rate of deformation; ε – degree of deformation; $U = f(U_{i-1})$ – the temperature of the material obtained from previously worked grains.

Temperature-speed strength characteristic determined by the experimental method on dynamometer of pendular type.

Temperature-speed strength characteristic (3), the coefficient of thermal conductivity (Λ) and the thermal diffusivity of the material (X) is a mathematical model of the material.

VI. MODEL OF THE CONTACT ZONE OF TOOL AND WORKPIECE

Tool (wheel) and detailed contact for a three-dimensional zone. The width of the contact area equal to the height of the circle. The arc length of contact (L_k) is calculated by the formula (4).

VII. GEOMETRICAL MODEL OF FORMATION OF SURFACE DURING GRINDING

At flat grinding by wheel periphery following movements of working bodies of the machine tool are carried out:

– rotary motion of the grinding wheel consisting of grains with speed V_k;

– linear motion of the workpiece on desktop with speed V_d.

At such movements grain runs into a workpiece and cuts off a material, leaving a microscratch in the form of sector of tor.

Calculation of the shape of the unit scratch is as follows. Along the length of the scratch with some interval (0.01-0.1 mm) are made lengthways scratch cuts. Thus, we get a lot of flat tasks. Then in each such section solve the task - finding the depth profile of the scratch. For this profile is divided into intervals y_1, y_2, y_3, ..., y_i by 0.01-0.1 mm, and for each interval calculating the depth profile. Through the equation of a circle $(y - y_0)^2 + (z - z_0)^2 = R^2$ can determine the height of the profile points belonging to the circle: $z = z_0 \pm \sqrt{R^2 - (y - y_0)^2}$. For our task $y = y_k$ $(k = 1,2,..., i)$, $z = z_i$, $y_0 = 0$, $z_0 = \frac{D}{2} + \frac{b}{2} - t$, $R = \frac{D}{2} + \frac{b}{2}$. Thus, the formula for calculating the height of each interval of the profile is provide (5).

We developed an algorithm that combines the model of the profile of a single scratch, longitudinal and cross-section overlap multiple scratches. On the basis of algorithm written program. The results of calculations in program is a relief of workpiece after cutting. Program allows to modeling formation of a surface from grinding by any quantity of grains, any granularity and circle structure and any speeds.

VIII. MODEL OF THE TEMPERATURE FIELD IN CUTTING ZONE

The mathematical description of three-dimensional temperature field in the grinding zone, with full consideration of the kinematics of the process - the speed range, feed rate, as well as the representation of abrasive machining process as a process of multiple microcutting abrasive grains leads to the second boundary condition for the heat equation in a moving environment.

As a result of mathematical transformations, changes and substitutions we separate the influence function of the heat source:

In the simulation are calculated temperature from the first heat source - the abrasive grain, which came into the contact zone first times, taking into account the temperature-speed of the strength properties of the material.

Then calculate the heat produced from the second abrasive grain.

It works in the environment already heated metal, so the intensity of the heat source is considered functionally related to the temperature of the preceding (presence of internal nonlinearity of the process):

$q_i = f(U_{i-1})$.

Thus, the function of the heat source from single grain can be represented in the form of recursion to describe the temperature field for any number of sources:

The summation of (1) for all sources can generate three-dimensional thermal model of abrasive machining processes:

IX. MODEL OF RADIAL COMPONENT OF CUTTING FORCE

Knowing when each grain is in contact area of the wheel and the workpiece, what volume of metal each grain are cutting, it is possible to calculate the radial component of cutting force of a single abrasive grain, S.N. Korchak [2]:

For calculation of force cutting by grinding wheel it is necessary to summarize forces from cutting by each grain which is in a zone of contact at some instant of time.

REFERENCES

[1] A.A. Dyakonov, Eestimation of a workability of materials in grinding processes / A.A. Dyakonov // The Master's thesis. — Chelyabinsk: Publishing house, SUSU, 2002.

[2] S.N. Korchak, Performance of the process of grinding of steel parts /S.N. Korchak. - Moscow: Mashinostroenie, 1974. - 280.