Creating an algorithm for improving the working surfaces of tools, using computer modeling

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Abstract. The issue in question relates to machine building, particularly to machining of metals. We used the approach and software environment allow comparison with other aforementioned approaches and software environments to more accurately simulate the stress state of the material of the tool and, thereby, to increase accuracy of the design parameters of the tool for specific operating conditions. Introduction of automated systems of metals is directly related to the device status monitoring process of metal cutting, work process and increase its efficiency in the conditions of limited use of staff. Tasks of further improvement of machine-building production are inextricably linked with the effective use of technological equipment. Improving the efficiency of CNC machine tools is limited "hard" daemon setting the specified modes of the metals, when not taken into account peculiarities of processing of a concrete detail and lays the modes for the most demanding conditions.

1. Introduction
Reliability, efficiency, and environmental safety of hydraulic turbines, pumps and other energy-converting machinery depend to a large extent on the quality of materials of bearing assemblies and end seals. Metallic antifriction materials used now cannot work without lubricating with the mineral oils, this complicates the construction of bearing assemblies and does not exclude the oil getting into the environment. Domestic power engineering still lags behind foreign companies in terms of the use of composite antifriction materials. Plastic deformation, shear and destruction of the crystal lattice during the machining of materials is accompanied by the formation of a substructure with a high concentration of defects, the problem of thermal and temporary stability of defective structures arising. This structural stability must be the guarantee of preserving the properties of products, especially it concerns their work during the whole period of their operation in real conditions. Despite the difference in technological solutions, all methods of machining materials have common features distinguishing them from static or low-speed deformation and relief cracking. The most important of them are the following: high stress gradient between deformable and non-deformable materials in the small volume of the transition zone, short duration of impact of external forces, the formation of a substructure with high density of defects of a crystal lattice, and, in some cases, the absence of significant macroscopic deformation [1]. Under the conditions of high-speed deformation of the material, an adiabatic shear occurs – the formation of local zones of increased plastic deformation, the energy of which is converted into heat, this decreasing
the yield limit with increasing temperature. When heat is emitted under the conditions of chip formation at a higher rate than its removal into cooling medium due to heat conductivity, heat is concentrated near strips or shear planes, this leading to the occurrence of the so-called adiabatic shear bands. During shear deformation, the transition from uniform deforming to adiabatic shear is determined by the magnitude and speed of deformation. Temperature in the region of the adiabatic shear depends on the magnitude and speed of the deformation and thermal physical characteristics of the material. Under the conditions of high-energy action, one of possible explanations of behavior of materials has been given on the basis of appearance of “highly excited states” in crystals. Under these conditions, the behavior of materials becomes non-linear, hydrodynamic nature of plastic flow is possible, a metastable structure and phase appear. In accordance with this theory, highly excited crystal becomes essentially a superposition of several structures, and the number of destroyed structural states far exceeds the number of atoms, this state of a substance being called atom-vacancy. In extreme conditions, when the process of chip formation occurs, the dynamic balance between crystalline and amorphous phases is even more probable. Abnormally intensive flows of defects occurring in these conditions cause much higher rates of transferring the substance. In general, the concept of structural transformations in the conditions of high-energy impact is formulated like this: into the crystal “energy is introduced, accumulative in the form of excited atom-vacancy conditions, which is then released as defect flows of standard or pulsed nature [1].

2. Results and Discussion
Techniques of examining high-speed processes which allow fixing structural changes in the process of chip formation are not quite perfect yet, and from the point of view of flow of various processes in material processing they are missing. Therefore, various aspects of phenomena of the interaction of a substance with thermal fields, plastic deforming and destruction of materials have not been fully understood due to the lack of complete theoretical and experimental data on the diagnostics of changes of the substance condition at atomic levels. Decomposition processes of oversaturated solid solutions, ordering and disordering of alloys, diffusion, self-diffusion, and mass transfer of substances, as well as the choice and recrystallization of deformed macro- and microobjects of metals have not been sufficiently studied. The study of these processes will allow more efficient use of mechanical processing, process control, and integrated methods of processing, as well as of the knowledge we have about physical phenomena [1].

The normal load on a cutting tool is a function of component cutting forces, and physical mechanical characteristics of the materials of the tool and the blank depend on the temperature in the cutting zone. But the actual contact area of the tool with the blank can be defined as the product of the number of contact points by their average size. The increase in contact area with the increase in wear leads to the growth of the number of contact points resulting in the increased heat flow. At the same time, the temperature in the contact zone affects the amount of heat flow and the nature of diffusion processes [1].

In the study of thermal processes, the dependences obtained by schematization and simplification of actual processes of thermal distribution are used. In general, these simplifications are as follows:

- heat sources are considered to be either concentrated or distributed according to the corresponding law which allows to describe quite easily the process of heat distribution;
- body shapes or components of the system are simplified;
- thermal physical quantities (heat conductivity coefficient, thermal diffusivity, specific heat capacity, and linear expansion coefficient) are taken in some cases as independent on temperature, what somewhat distorts the actual process, but significantly simplifies mathematical expressions.

Study and description of main patterns of flowing of various processes during machining allow one to approach the explanation of mass transfer in the conditions of chip formation, formulate the main principles of intensification of different processes during metal processing. The study of the processes of high-speed deforming and destruction of materials allows us to judge, on the one hand, the dynamics of the substance condition change in substructural and atomic levels by the nature of the processes
course, and, on the other hand, to develop qualitatively new physical principles for intensifying the methods of material processing, the control of processing, and the diagnostics of the state of a cutting tool. Based on a comprehensive study of the relationships of deformation, post-deformation and material destruction processes, structural changes in the conditions of high speed processing, a scientifically determined approach to the use of the results obtained in making new control methods is possible.

One of the problems is the selection of friction pair – a metal alloy and a method of its surface treatment. The sufficiently high surface hardness of carbon plastics (compared to, e.g., to fluoroplastic-4), special physical and chemical properties require high mechanical characteristics of the response pair, which leads to increased cost of the product [2, 3, 4].

In mechanical engineering, technologies of changing physical and mechanical state of the part surface are widely used. Figure 1 presents a diagram illustrating various technological measures aimed at changing the physical mechanical (physical chemical) condition of both the whole material from which the friction pair element is made and of a thin surface layer. Experiments on metal samples are still crucial for calculating the properties of a material, checking the model, adjusting it to solve the problems of increasing wear resistance. Due to the use of computer simulating, they decrease dramatically in volume, complexity and cost [2, 3, 4].

Making block-diagrams of programs for calculating thermal fields by the finite element method greatly simplifies and reduces the cost of making the improved surface layer of the tool and opens up possibilities for computer modeling of the quantities of these surfaces without significant expenses for laboratory physical experiments.

Figure 1 presents a diagram illustrating the methods that allow changing physical and mechanical state of the surface layer of friction pairs.

**Figure 1.** Diagram illustrating methods that allow changing physical mechanical state of the surface layer of friction pairs.
The given methods can be divided into the following groups:

- a group of technologies associated with the bulk quenching – or thermal treatment aimed at increasing the material hardness;
- technological operations aimed at the surface layer hardening, e.g., by high-frequency currents;
- technological operations associated with special kinds of surface thermal processing: cementing followed by hardening and tempering, or methods of nitriding, cyaniding, sulphocyaniding, etc.;
- technological operations associated with plating with galvanic coatings: chroming, anodizing, cadmium coating, cuppering, silvering, etc.;
- mechanical technological operations of hardening kinds of surface processing: regular microrelief coating; vibrating roller burnishing; roll and ball forming, etc.;
- methods of plasma spraying which may be divided into two groups: high temperature plasma; low temperature plasma;

**Figure 2.** Block-diagram of the program implementing the calculation of thermal fields by the finite element method.
− methods of ion-vacuum surface modification, or they are also called ion implantation;
− methods of explosive surface hardening;
− methods of laser surface hardening.

One of the most promising methods is the method of plasma spraying which allows modifying the material surface to required technical parameters, such as hardness, roughness, residual surface stresses. However, application of plasma spraying is accompanied by the number of difficulties, such as the occurrence of a defective layer of extending residual stresses, and microfissures.

![Figure 3](image-url) Block-diagram of the program which implements the implementing calculation of flat stress state.

The given defects occur if the spraying technology is wrong or it is not observed. Development of hard facing technology is accompanied by examining on natural samples. To reduce the cost of examinations, it is possible to use computer simulating for hard facing processes. Compared to routine “natural” experiments, computer simulating requires preliminary efforts to create models in the form of...
software supply. However, the following experiments on the model prove to be more operative, cheap and effective.

For the purpose of rational spraying parameters, it is possible to use modern computers and application package implementing calculations by the finite element method. The main idea of the finite element method is that any analog quantity such as temperature, pressure or displacement can be approximated by a discrete model that takes place on a set of piecewise continuous functions defined on a finite number of subdomains.

Piecewise continuous functions are defined by the way of values of analog quantity in the finite number of points in the considered domain. To define the thermal deformation fields, the shape of an object for which calculations will be made is first set. Then the shape is broken down into elements. It is thought that on each element all characteristics of the material such as temperature, stress, deformation, displacements, as well as physical chemical properties of the material do not change, or change linearly. The calculation of thermal fields is made according to the algorithm (figure 2), and the calculation of stresses is made according to the algorithm (figure 3). Particularly, the description of physical, chemical and mechanical processes has been presented in the literature [1, 5, 6].

3. Conclusion
In the presented work the materials were compiled on the basis of the calculations made and computer simulating of the surface hardening process at the “Automata” department in the SPbPU, which allow us to recommend the given programs for application of wear resistance coatings in mechanical engineering.

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