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# Intellectual Control System of Processing on CNC Machines

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**Abstract.** Scientific and technical progress makes great demands for quality of engineering production. The priority is to ensure metalworking equipment with required dimensional accuracy during the entire period of operation at minimum manufacturing costs. In article considered the problem of increasing of accuracy of processing products on CNC. The authors offers a solution to the problem by providing compensating adjustment in the trajectory of the cutting tool and machining mode. The necessity of creation of mathematical models of processes behavior in an automated technological system operations (OATS). Based on the research, authors have proposed a generalized diagram of diagnosis and input operative correction and approximate mathematical models of individual processes of diagnosis.

## Introduction

We can talk about the crisis in the metal working industry, having regard to the present state of the global economy, which is in shambles. The enterprises of engineering branch are faced the problem of reduction of production costs. Under such conditions, absence of possibility attracting additional capital becomes impossibility of performing logistical reequipment, which affects the competitiveness of products. Scientific and technological progress can't be stopped, in fact every year there is an acceleration in the rating of its development. All the new discoveries in fundamental and applied areas of knowledge makes it possible to create a fundamentally new equipment. Manufacturing industry is the last limiting link in a long chain from the scientist to the final consumer. It isn't enough to make a discovery also it is necessary to develop technology of processing of the product received as a result of discovery which is possible for processing on the available equipment. At this stage of historical development the leading role in manufacturing industry is played by metal working. Therefore, rates of development of scientific and technical progress, finally, depend on a level of development of opportunities of metal-working industry. The basis of metal-working industry is cutting process. Realization of this process allows to receive everything that variety of vehicles and machinery which so simplify our life. Process of cutting of metals, despite nearly one and a half centenary history of studying, remains misunderstood [1-6]. And it definitely imposes restrictions on possibility of production of the set quality with the minimum material expenses. During an era of competitive struggle between the separate enterprises of engineering branch, advantages are got by the one who is capable to use most effectively resources of the available processing equipment for release of high-quality production. Possibly to achieve the solution of this production task due to increase of effective

management of cutting process. There are various approaches to increase of effective management of processing on the metal-cutting equipment. Early studies and the first discoveries in this branch of knowledge were made in the 50th years of the XX century, along with emergence of the first systems of the computer numerical control (CNC) [7-8]. It is necessary to tell that emergence of CTC systems led to emergence of interest in this area. At the beginning increase of effective management of process of cutting was reduced to stabilization of separate output parameters. Was considered, for example, that the technological system will work most effectively if forces of cutting will remain constants in time. Development of CTC systems went on the way of complication of process of management of movement of executive bodies – from position systems to planimetric that, finally, resulted in insufficient efficiency of approach of the management of processing based on stabilization of forces of cutting. In this regard adaptive control systems of processing arose and began to develop. Such systems trace a condition of processing equipment in processing and to a campaign of different detection of errors introduce amendments in the operating trajectory (OT) of movement of executive workers of bodies and the modes of processing. It is necessary to notice that in processing there is a set of various errors. All variety of errors can be reduced to the following reasons:

1. – wear of the rubbing surfaces of processing equipment;
2. – change of spatial situation and a geometrical form of elements of processing equipment, under the influence of the efforts arising in the course of cutting;
3. – change of spatial situation and a geometrical form of elements of processing equipment, under the influence of thermal deformations;
4. – wear of an edge of the cutting tool in processing;
5. – errors of production and assembly of elements, processing equipment;
6. – unforeseen refusals, both separate knots, and processing equipment in general.

All these phenomena arising in technological system doesn't work separately. They works closely intertwining, mutually make an impact at each other thus on the final accuracy of processing. At this stage of development of science and equipment management of processing on CNC machines, it is carried out by means of intellectual systems of adaptive control, i.e. systems controlling technological parameters of system in the course of its work. So, for example, the systems of adaptive control of the RENISHAW company allowing to watch wear of the cutting tool and linear movements of executive bodies of the equipment are well-known. Such systems work in the mode, so-called, real time, i.e. from the moment when the intellectual system of adaptive control determines parameters of a condition of the equipment, till the moment when after processing of these data, changes are made to the operating program (OP), will pass some period, thus the state the equipment will manage to change, thus, we appear in Akhiless's and turtle situation from a known aporiya of Zenon Eleysky. At the moment known control systems of processing on CNC machines allow to consider the changes influencing processing and to bring the corrections compensating errors, caused by such influences as temperature (temperature deformations of a mainspindle and the tool), the cutting force (deformation of working bodies of machines), wear of the cutting tool (shift of an edge in machine coordinates) and tension on the cutting wedge (independent refusal of FRI). But still developed approaches and devices for optimization of process of cutting owing to some difficulties are not introduced. Such complexity, in particular, is that application of the developed approaches assumes intervention in configuration and the software of original expensive processing equipment. In the presence of possibility of failure and removal from guarantee maintenance use of such systems in not certified execution seems unattractive for the enterprise [9-11]. So, for example, transfer of the equipment to management of CNC of system with open architecture is necessary for implementation of the corrections compensating deformations in processing equipment. All aforesaid forces to look for new approach in the solution of this problem which unitary enterprise directly at a creation stage consists in adjustment. In most cases development unitary enterprise for CNC machines is conducted using systems of the automated design (CAM), or carried out by the built-in simulars, directly on the CNC control panel. Therefore, the errors arising at implementation of the operating programs created by CAM system or the CNC control panel on real technological system will be inherited by the processed detail. The wide circulation in modern

machining production of CNC machines leads to emergence of one more problem demanding the decision – decline in quality of production in use by the choosen technological system . The matter is that any material object is subject to such phenomenon as aging, i.e. gradual deterioration of its initial characteristics. The technological system isn't an exception of this rule, it is also subject to deterioration of the operational characteristics over time, and this process proceeds the quicker, than possibilities of technological system are used more intensively. One of the main operational characteristics of technological system is its ability to provide the demanded dimensional accuracy and quality of the processed surface at the minimum production expenses. The solution of this problem was prompted by technology of construction of high-rise buildings in the conditions of difficult soil when the building is under construction with an inclination so that at the end of construction the building by gravity adopted the vertical provision. This approach can be used in the solution of problems of increasing dimensional accuracy of machining on CNC machines consisting in transformation of the geometrical model created in CAD-system by such change of its form that in processing the errors connected with errors of technological system were compensated. Realization of this approach, requires creation of the neural network mathematical models describing behavior of technological system in processing, distinctive feature which there will be an ability to self-learning ability.

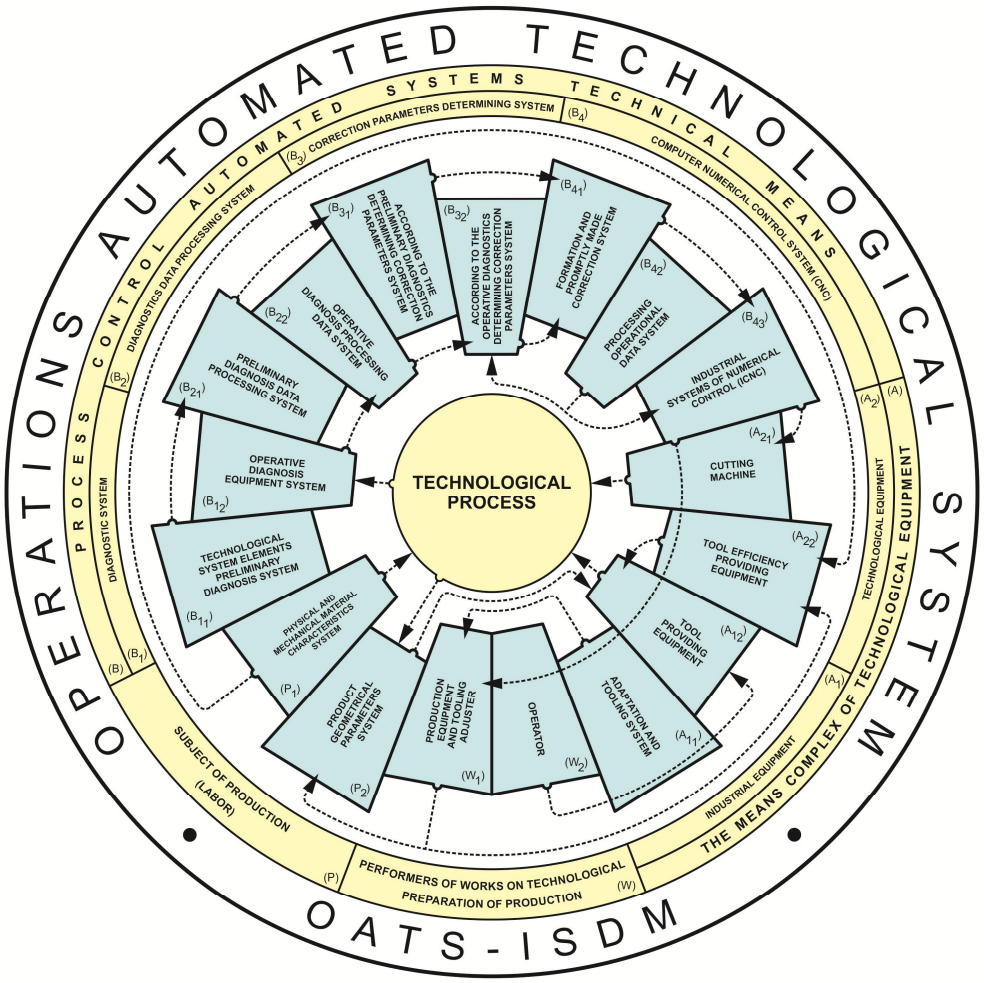


**Figure 1.** Structure of operations automated technological system (OATS).

**2. Research methods**

The methodology of transformation of geometrical model of a detail taking into account, the arising errors of processing consists of the following consecutive stages:

1. – creation of geometrical model of a detail by means of systems of solid-state modeling (CAD-system);

2. – definition of a geometrical form of a detail as a result of influence of the thermal and power loadings arising in the course of machining by means of systems of the final and element analysis (CAE system);

3. – modification of initial geometrical model of a detail, based on results of performance of the previous stage.

This methodology creates possibility of input of corrections at a development stage unitary enterprise for the CNC machines. The defined deviations from nominal rates of the sizes are compensated by input of correction coefficients, so that the arising errors were compensated in the course of realization unitary enterprise. The developed methodology is entered in the scheme of the automated technological system of operations (OATS) presented in figure 1 offered by authors.

system, on the basis of self-training neural network model which scheme is submitted in figure 2.

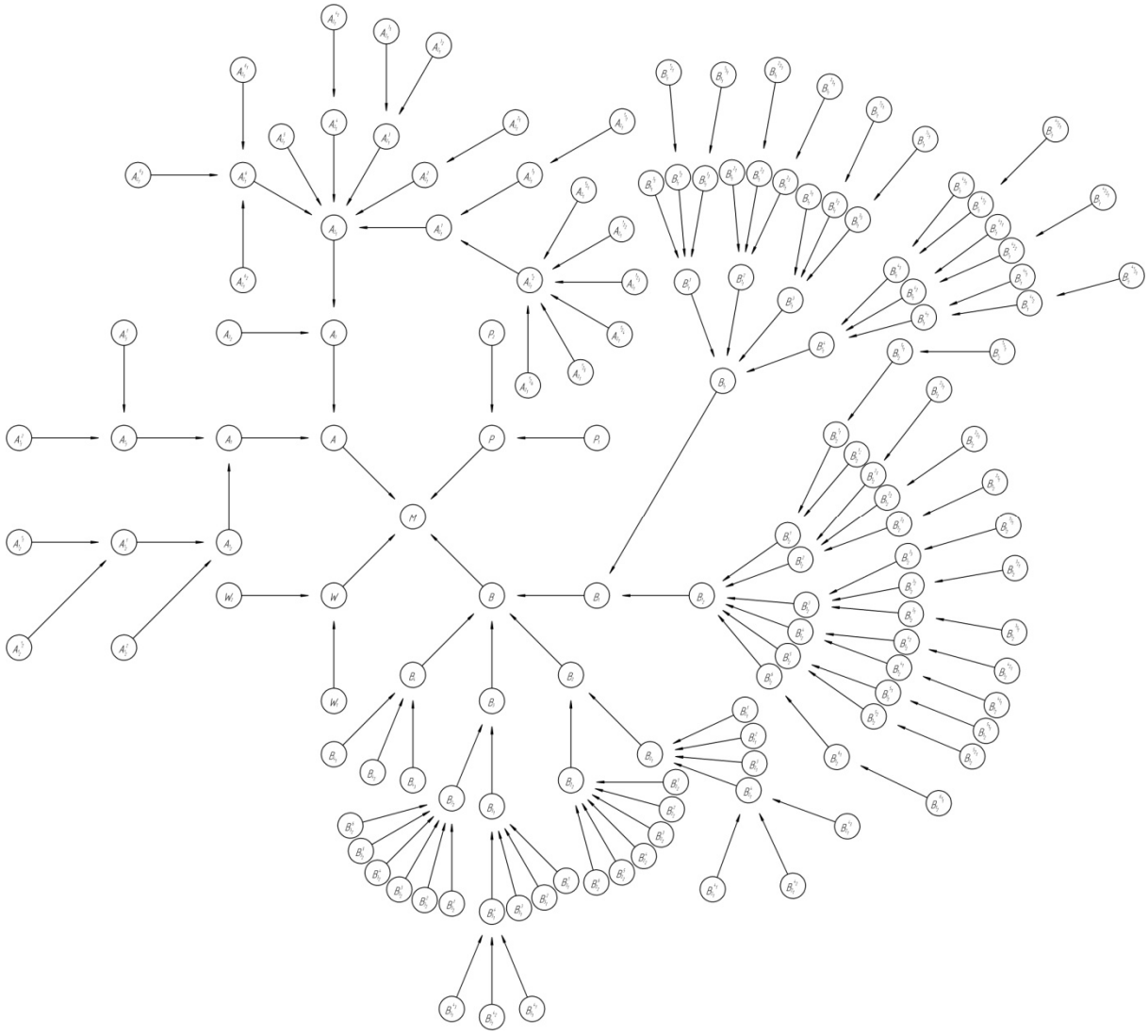

**Figure 2.** The neural scheme of representation intellectual control system of processing on CNC machines.

1 structure of ATSO represented in drawing isn't full and exhaustive (elements from which ATSO consists are provided in table 1), but sufficient to approach a question of mathematical modeling and development of mathematical models of various processes proceeding in it and necessary for development of an intellectual control system of processing on CNC machines. The problem of realization of this methodology is in the following that for the second stage, i.e. definition of a geometrical form of a detail as a result of influence of the thermal and power loadings arising in the course of machining by means of systems of the final and element analysis (CAM system) data which can't be received without carrying out preliminary and expeditious diagnostics. [12-15] Expeditious diagnostics of researches are necessary, therefore each new unit of processing equipment requires creation of own mathematical models describing behavior in the course of machining. The acceptable solution of this task will be creations of universal mathematical behavior models of technological

The presented scheme of self-training neural network model is reconsideration of structure of OATS represented in figure 2. For creation of this scheme subsystems and elements the making OATS were described, the short list of the most important parts is presented in table 1.

**Table 1.** Elements the making OATS.

| Symbol | Name |
|---|---|
| $M$ | Operations automated technological system (OATS – ISDM) |
| $P$ | Subject of production |
| $P_1$ | Set of mechanical-and-physical material properties of a subject of production (work) |
| $P_2$ | Set of geometrical parameters of a subject of production (work) |
| $W$ | Contractors on technological preparation of production |
| $W_1$ | Serviceman of processing equipment and equipment |
| $W_2$ | Operator of processing equipment |
| $A$ | Set of means of technological equipment |
| $A_1$ | Industrial equipment |
| $A_{1_1}$ | Set of adaptations and means of industrial equipment |
| $A_{1_2}$ | Set of means of tool providing |
| $A_2$ | Processing equipment |
| $A_{2_1}$ | Metal-cutting machine |
| $A_{2_2}$ | Set of means of ensuring of operability of the tool |
| $B$ | Process control of an automated system technical means |
| $B_1$ | Diagnostic System |
| $B_{1_1}$ | System of means of preliminary diagnostics of subsystems and elements of technological system |
| $B_{1_2}$ | System of means of expeditious diagnostics of subsystems and elements of technological system |
| $B_2$ | System of data processing of diagnostics |
| $B_{2_1}$ | System of data processing of preliminary diagnostics of technological system |
| $B_{2_2}$ | System of data processing of expeditious diagnostics of technological system |
| $B_3$ | System of determination of parameters of corrections |

| | |
|---|---|
| $B_{3_1}$ | System of determination of parameters of corrections according to preliminary diagnostics |
| $B_4$ | System of numerical program control by the machine (CNC) |
| $B_{4_1}$ | System of formation and expeditious input of corrections |
| $B_{4_2}$ | System of operational data on processing |
| $B_{4_3}$ | System of numerical program control by the machine (PCNC) |
| $B_{3_1}{}^4$ | System of determination of parameters of corrections according to preliminary diagnostics of temperature deformations |
| $B_{3_1}{}^{4_1}$ | System of determination parameters of corrections according to preliminary diagnostics of temperature deformations from mainshpindel knot |
| $B_{3_1}{}^{4_2}$ | System of determination of parameters of corrections according to preliminary diagnostics of temperature deformations from a tool head |
| $B_{3_1}{}^{4_3}$ | System of determination of parameters of corrections according to preliminary diagnostics of temperature deformations of the back center |

**Summary**
The offered approaches to mathematical modeling of the processes proceeding in ATSO allow to solve a problem of creation of an intellectual control system of processing on CNC machines therefore increases of dimensional accuracy of machining. The positive effect from introduction of this system is connected with reduction of the production expenses spent for technological preparation of production of products of engineering production.

**References**
[1] G S Andreev The stress state of the cutting part of the cutter with periodic cutting Durability of the cutting tool (1969) 28-37
[2] A I Betaneli Communication method of calculating the strength of the cutting part of the tool, Bulletin of engineering. **2** (1965) 16-18
[3] A A Lasukov, P A Chazov, A V Barsuk Investigation on the Elemental Chip Formation Process in Hard-to-Machine Material Cutting Applied Mechanics and Materials **682** (2014) 504-509
[4] V F Bobrov Determination of stresses in the cutting part of the cutting tools High-performance cutting in mechanical engineering (1966) 228-233
[5] A M Geniatulin Holographic method research strained elements of assorted cutters Optical-geometrical methods in the study of deformations and stresses and their standardization, Gorky (1982) 83-84
[6] R Yu Nekrasov, A A Starikov, M A Korchuganov Performance assessment of carbide tooling under thermal and loading conditions Applied Mechanics and Materials **682** (2014) 414-417
[7] A I Afonasov, A A Lasukov Elementary Chip Formation in Metal Cutting, Russian Engineering Research **3** (2014) 152–155
[8] R Yu Nekrasov, I V Soloviev, U S Putilova Laser interferometry method of stress determination in loaded cutting tool parts Applied Mechanics and Materials **698** (2015) 537-541
[9] M B Gordon Methodology and some results of a study of patterns of distribution of the friction forces and tangential stresses on the contact length of the chip from the front surface of the cutter Issues in the application of cutting fluids in machining metals (1965) 41-44
[10] U S Putilova, Yu I Nekrasov, A A Lasukov Loading of the manufacturing systems elements in the process of unsteady mode cutting and the models of their arrangement deviations, Applied Mechanics and Materials **682** (2014) 192-195

[11] R Yu Nekrasov, A I Starikov, I V Soloviev Simulation of technological systems for diagnosis and management machining with CNC Applied Mechanics and Materials 770 (2015) 617-621
[12] R Yu Nekrasov, U S Putilova, A I Starikov, D A Kharitonov Diagnostics of cut-layer deformation and rational tool loading in numerically contolled lathes, Russian engineering research **34** (2014) 826-828
[13] A A Lasukov, A A Mokhovikov Influence of modified layer of tool on stress - Strain state of cutting wedge, Proceedings (2012)
[14] R Yu Nekrasov, A I Starikov, A A Lasukov Entering the operative correcion machining processes CNC Materials Science and Engineering **91** (2015)
[15] A A Lasukov Selection of machining conditions in terms of the temperature dependence of chip formation, Russian Engineering Research **9 (**2015) 679–681