ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

Method for Determining the Optimal Cutting Modes for Machine Tools with Numerical Program Control

A.M.Abduvaliev

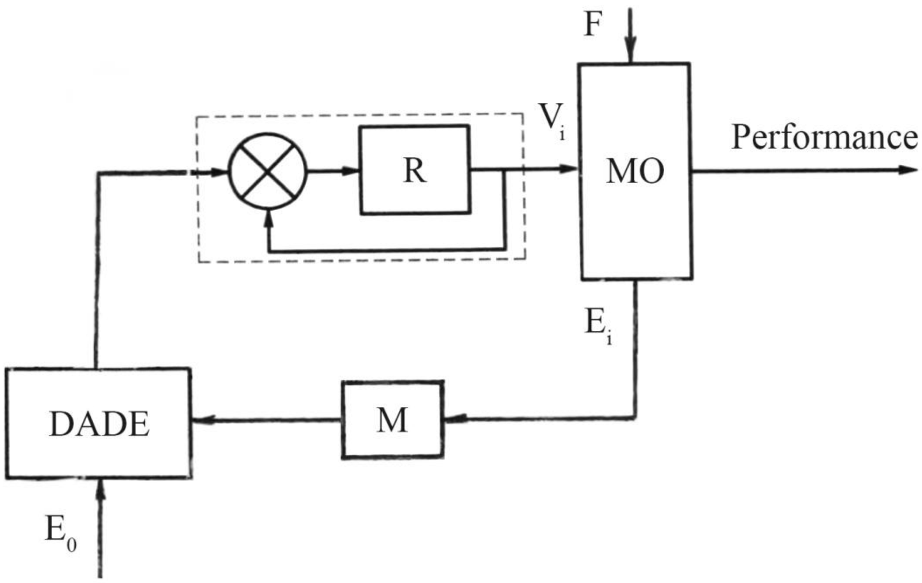
The Department of the Technical Operation of Aircrafts and Equipment, Tashkent State Technical University, Uzbekistan

ABSTRACT: The method of determination of optimal cutting conditions for metals with numerical control is investigated in the article. The developed method is based on the analysis of the dependence "thermo electromotive force – cutting speed".
The results of experimental studies are presented. The application of the method increases the productivity, efficiency, reliability and stability of machining of parts on CNC lathes in flexible production systems.

KEYWORDS: flexible production systems, machine with numerical control, adaptive control systems, cutting modes, control, thermo electromotive power, cutting speed.

I. INTRODUCTION

Nowadays while creating flexible production systems on machines with numerical control (MNC), systems of multi-



parameter control and control of machining processes are becoming increasingly widespread [1].

Figure 1. Scheme of the adaptive control system based on the measurement of the thermoelectric power.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

Where: E_0– initial value of thermo EMF; E_i – current value of thermal EMF; V_i – current cutting speed; M – Measurer; R – Regulator; DADE – Device for Automatic Determination of the Extremum; MO – Managed object; F – Disturbing Factors in the cutting process (cutting depth, work piece hardness, etc.)

These systems recognize the state of the object by monitoring more than one (n + 1) parameters using various measuring means (measuring heads of the parts and tools, vibration sensors and thermo-electric driving force) at all stages of the process (installation and identification of workpieces, tool setting, processing process).

One of the important components of the multi-parameter control system is adaptive control systems (ACS) on CNC machines. The data of ACS provides an automatic adaptation of the modes of processing parts according to a certain criterion to changing processing conditions, carried out on the basis of information obtained directly in the process of cutting. Based on the information obtained on the current state of the cutting process of the automatic control system, increasing or decreasing the removal of metal from the workpiece by means of a corresponding change in cutting and feeding speed, maintains a certain parameter of the cutting process constant. Most often, the cutting force, temperature, acoustic emission signals, torque value, etc. are selected for this purpose and optimal values of such criteria as accuracy of processing, productivity, cost of processing are obtained.

The analysis showed that one of the most informative indicators of the cutting process is the change in cutting temperature or its equivalent, the thermo electromotive force (thermo EMF), which is due to the joint influence of the allowance for processing, fluctuations in the hardness of the processed material, wear of the cutting tool, etc. [2].

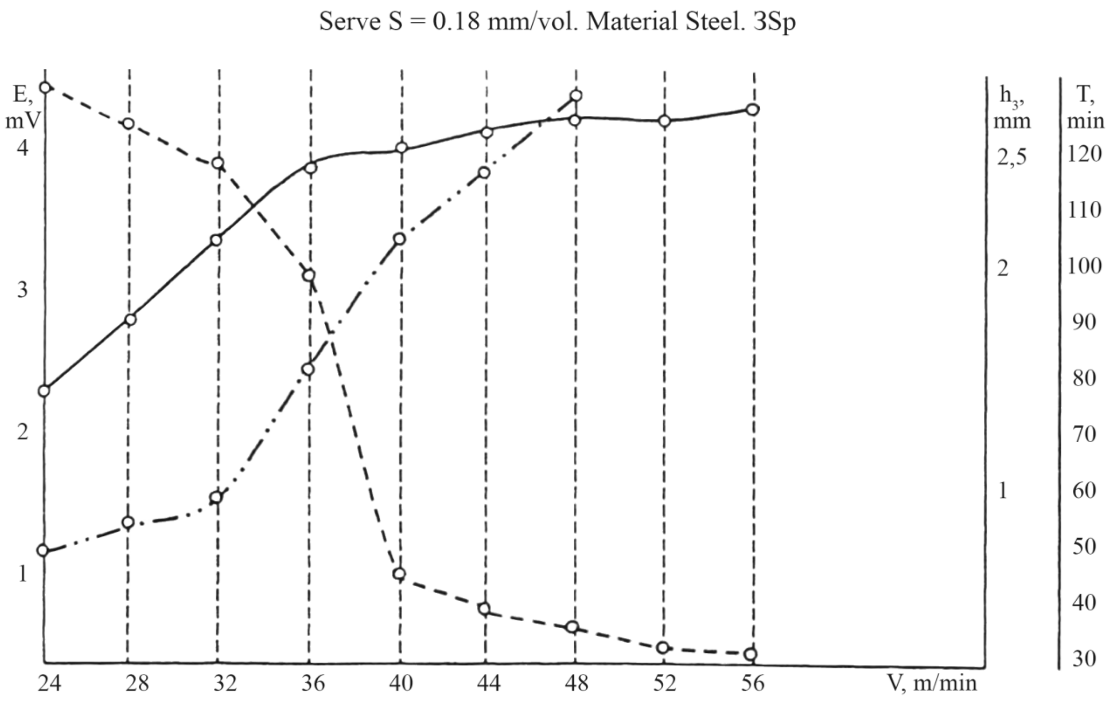


Figure 2. The results of experimental studies.

Where: —— – Value of the electromotive force (EMF); - - - – Value of the cutter tenacity (T); —· · —– wear value on the rear surface of the cutter (h_3)

Based on the analysis of the dependence "thermo electromotive force – cutting speed", a method has been developed for determining optimal cutting conditions for CNC lathes of flexible production systems.

II. SIGNIFICANCE OF THE SYSTEM

While processing parts on CNC lathes, the level of optimality of the accepted cutting modes depends on how accurately the initial information characterizes the actual conditions of the cutting process and the initial parameters adopted during the development of the control program (size of allowance, hardness of the processed material, rigidity of the technological system and etc.). In fact, these parameters are disturbing factors and do not remain constant during the cutting process. Therefore, the traditional methods for setting cutting conditions are based on an approximate idea of the cutting process and the expected values of its parameters. Using at the same time the methods and the standard materials do not completely take into account the diversity of technological methods for obtaining blanks, as well as the state of the technological system.

The presence of a spread in the initial parameters of the processing process forces the reduction in the probability of machining, reducing the wear of the cutting tool and increasing its consumption, as well as protecting against emergencies. On the other hand, the execution of the machining process with constant cutting conditions at the specified spread of the initial parameters of the machining process leads to significant variations in the cutting force. This, along with a change in the rigidity of the technological system, leads to significant fluctuations in the elastic displacements of the latter and, as a consequence, to errors in the processing of parts.

The random nature of the change in the allowance and hardness of the workpiece material changes the wear rate of the cutting tool and leads to a deviation of its actual resistance from the specified one. These factors lead to a decrease in productivity, the spread of processing quality indicators, underutilization of reserves to reduce the cost of processing parts.

In this regard, the development of automatic control systems by processes of machining of parts and the method of selecting optimum modes of cutting conditions on CNC lathes in flexible manufacturing systems is relevant.

III. LITERATURE SURVEY

Scientific researches aimed at creating methods, algorithms and software of automatic control systems by technological processes of machining on CNC machines in flexible production systems are conducted in leading scientific centers and higher educational institutions of the world in the USA, Great Britain, Japan, Russia, France, China, Italy, Germany and others [3].

In publications of international companies and scientific centers, such as GERMO, Yamazaki, Renishaw, Moscow State Technical University named after N.E. Bauman, Experimental Research Institute of Metal-Cutting Machines (Russia), Moscow State Technical University "Stankin", Institute of Engineering Science named after A.A.Blagonravov (Russia), National Technical University of Ukraine "Technical Institute of Kiev" (Ukraine) and others [4,5,6,7] noted that the development of ACS is in the direction of improvement, taking into account the requirements of modern industrial relations, the production of competitive and quality products.

As a result of research conducted in the world on the development and achievement of automatic control systems by technological processes of machining, it is considered expedient to carry out research on improving them, the system approach and developing systems using new informative features of the processing, algorithms and methods, taking into account the influence of external technological influences and parameters of the machining process.
Currently, CNC machines are used ACS providing a given accuracy of certain parameters of technological processes of machining parts. However, in scientific works, the problem is not considered taking into account the influence of incoming technological factors, parameters of the machining process and the features of the functioning of the flexible production system. Proceeding from this, the optimization problems of choosing the optimal cutting conditions,

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

providing high accuracy, productivity and efficiency of the technological process of machining of details are not investigated.

In connection with the above, there is a need for further improvement, based on the use of new informative parameters of the cutting process and the creation of effective automatic control systems by machining processes that ensure the selection of optimal cutting conditions on CNC machines in flexible production systems.

IV. METHODOLOGY

Qualitative characteristics, efficiency, adaptability can be significantly increased at the design stage of the study. In this connection, the automatic control system was developed on the basis of measurement of the thermoelectric power (Fig. 1).

A sample of the structural steel to be examined is subjected to turning by a high-speed (or carbide) cutter. The natural thermocouple circuit is pre-assembled according to a well-known principle scheme. The circuit consists of a millivoltmeter connected to one pole by a conductor having contact with the cutter, to the other pole a conductor having a contact and a processed sample.

Installation on an CNC machine tool with an insulated cylindrical specimen made of structural steel is fixed in the tool holder by cutting off the cutter from the machine and connecting the contacts of the mill voltmeter to the current collector from the rotating sample and cutter

Cutting starts with the minimum spindle speed (at constant feed and cutting depths). Gradually increasing the speed (cutting speed), observing the reading of the measuring instrument and fixing the value of the thermoelectric power for each cutting speed (Fig. 2).

Cutting at each speed is carried out to the established value of the instrument reading. Record the thermo EMF values for each speed in the table. At the same time, without removing the chisel from the machine, its condition on the front and back surfaces is controlled using a Brinell's magnifying glass. With increasing cutting speed, the wear of the tool along the main rear surface increases, we assume for normal blunting the normal wear on the back surface of the tool hz = 0.3-0.5 mm. If the wear on the rear surface exceeds the accepted blunting criterion h> 0.5 mm, it is necessary to remove the cutter and trim it on the top of the back surface, retaining the geometrical parameters of the tool, and then proceed to the next higher cutting speed. According to these data, the curve of the dependence "thermo EMF - cutting speed" and "wear on the back surface - cutting speed" is constructed. On the curve of dependence "thermo-EMF-cutting speed" is determined by the area in which starting from a certain cutting speed, the value of the thermal EMF does not increase with increasing cutting speed. The cutting speed, starting from which the curve breaks and the value of the thermal EMF does not increase with increasing cutting speed in the "thermo-EMF-cutting speed" relationship, is the maximum allowable workpiece-cutter for the given pair, with other constant values (tool geometry, feed, depth of cut). Increasing the cutting speed above this leads to a catastrophic wear of the cutting tool.

This cutting speed, where the curve breaks (in the example of Fig. 2 Vmax = 36 m / min), and is the maximum cutting speed for a given pair: the processed structural steel is the material of the cutting tool.

Thus, an objective informative criterion has been obtained, firstly, for determining optimal cutting conditions; secondly, it allows creating effective diagnostic devices and devices that can be successfully used in the design of advanced automatic control systems by the machining process.

On the basis of an informative feature the method for controlling the cutting modes on CNC machines is developed, consisting of the following main stages:

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

1. Continuous measurement of the temperature (thermo EMF) in the cutting process;
2. Operative processing of measurement results and determination of the dependence E = f (V);
3. A graphic curve is plotted for the dependence of "thermo EMF - cutting speed";
4. On the curve of the dependence E = f (V) - "thermo-EMF - cutting speed", determine a section in which, beginning with a certain cutting speed, the amount of thermal EMF does not increase (slower rate of change) with increasing cutting speed;
5. Determination of the break point of the curve, where starting from which there is no increase in the magnitude of the thermoelectric power;
6. Selection of the cutting speed value corresponding to a given thermoelectric power;
7. This cutting speed is the maximum value of the cutting speed for the given machining conditions, as cutting above this speed leads to a catastrophic wear of the cutting tool;
8. Setting the selected cutting speed on the CNC machine.

Processing of measurement results - Ei is performed in a dynamic mode. Therefore, one of the important questions is, the method of determining the break point, at which, starting with a certain cutting speed, there is no increase in the value of the thermal EMF with an increase in the cutting speed.

Based on the analysis of existing various methods for constructing surfaces, curves, and experimental studies, the following methods for solving the processing of the solution of this problem are defined:
1. The method of successive comparisons of the current values of thermoelectric power (Fig. 3).

This method is based on a comparison of the previous - E (i-1) and current - Ei measurement of the thermoelectric power. If the difference between the previous and the current value of the thermal EMF corresponds to the condition (Ei-1 - Ei) ≤ΔE (where, the value of ΔE = 0.1 [mV] (Fig. 2) is taken on the basis of the experimental studies). This value is taken as the break point, i.e. to set the maximum cutting speed.

2. A method of sequential comparison of approximating curves.
Using the graphical curve of the dependence "thermo emf - cutting speed" between two points, i.e. the previous and current values are used to construct the corresponding curves. Thus, in the example of Fig. 2, we obtain 8 equations of straight lines - Yi = KXi + B.
Solving a system of equations from Y1=KX1+B and Y2=KX2+B, we obtain K1= Y1 - Y2/X1-x2 where, In= X1*Y2 – Y* - x2/ X1-x2
Comparison of the coefficients-K of each equation of the curve to determine the break point of the curve-e=f (V).

3. The construction of curves by the method of least squares consists of the following stages (Fig. 2):
- in the cutting speed range (V1 = 24 m / min to V4 = 36 m / min) with increased temperature increase, the construction of the approximated curve by the least squares method - Y1 = Kx + b;
- in the interval of cutting speeds (V4 = 36 m / min and V9 = 56 m / min) with slow growth of temperature (V4 = 36 m / min and V9 = 56 m / min) the construction of the approximated curve by the least squares method - Y2 = Kx + b;
- determination of the intersection point of two curves Y1 = Kx + b and Y2 = Kx + b;
- a certain point will be a break point providing the maximum cutting speed (for example, Fig. 2 Vmax = 36 m / min).

Depending on the equipment of this or that algorithm of processing of the measured values, there is a need for a constructive change in the control systems of the elements of the CNC system or communication with the upper-level computer, for calculations, software storage and intermediate calculation results, etc.

The developed system according to the classification of ACS is a search engine. In the automatic control system, the optimal solution is found by gradual step change in the control vector (cutting speed) in the direction obtained from the results of trial changes in the coordinates of the control vector. The algorithm of the ACS program determines the direction of increase in the change in the cutting speed and organizes the movement toward the maximum along the controlled coordinate until the derivative of the criterion function from this coordinate is zero (or becomes close to zero).

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

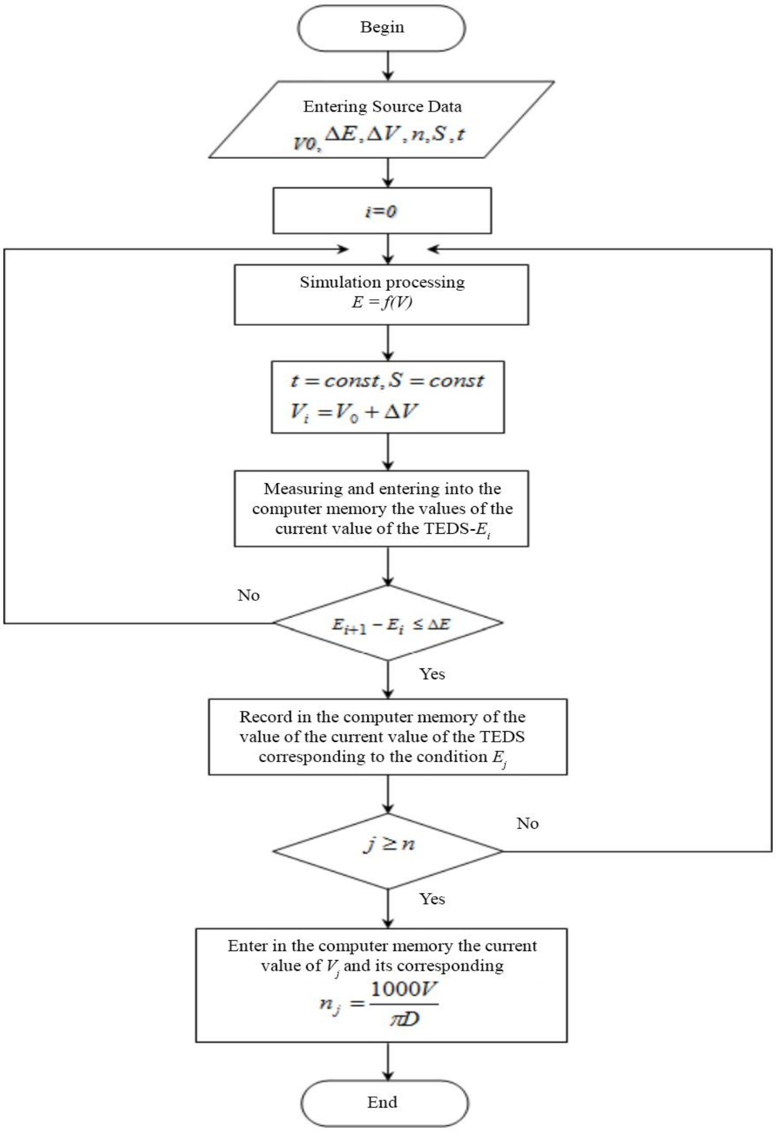


Figure 3. Block diagram of the algorithm for determining the optimal cutting conditions.

In the ACS, the process of turning the control parameters is the rotational speed of the spindle. Due to the fact that this direction is new, at the first stage the value of the feeding is carried out –, the depth of cutting – t and the cutting angles remain constant. Control effect is formed by the ACS according to the driving signals, which are generated by the computing device of the computer by continuously determining the values of the thermo EMF by the measuring means. If in the process of processing a significant influence of external factors leads to a displacement of extreme characteristics, then the cycle of reaching the extreme is repeated.

Figure 3 shows a block diagram of the algorithm for controlling the cutting regime on CNC machines based on the function of dependence E = f (V) – the value of "thermo EMF – cutting speed" on using the method of successive comparisons of current values.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

In the input block the following input data are entered: S [mm / rev] = const - feed-rate value; t [mm] = const - cutting depth; V1 [m / min] - the initial value of the cutting speed; ΔV [m / min] - range of change (increase) in cutting speed values [mm /

rev]; ΔE [mV] - a given value that determines the slowdown in the rate of change in the value of the thermal EMF; m - the required number of measured thermoelectric power - Emi [mV], to determine the maximum cutting speed Vmax [m / min]; D [mm] is the diameter of the workpiece.

The machining process starts with the initial cutting speed - V0. The gradual increase in the current value of the cutting speed - Vi is realized due to the increase in the range of the values of the cutting speed - ΔV. Processing at each speed is carried out to a steady state (usually up to 1 second). At each current cutting speed, the device measures the value of the thermal EMF - Ei and writes it to a separate memory block - B1 computer. Further, the information is processed and the deceleration point (break point) is determined. If the difference between the previous - E (i-1) and the current - Ei value of the thermoelectric power corresponds to the condition (E (i-1) - Ei) ≤ΔE (where, value ΔE = 0,1 [mV] experimental studies), then in this case these values of thermal EMF - Ej are written in a separate memory block - B2 computer.

Thereby, the program processes the incoming current values of the thermal EMF signals -Ei and compares it with each previous value -E (i-1) and determines where the rate of change of the thermoelectric power is slowed. Determination of the maximum current value of the cutting speed - Vjmax corresponding to the slower rate of change in the thermal EMF, is made based on a certain (specified) number of measured values - m, subject to the condition (E (i-1) - Ei) ≤ΔE. The experimental studies carried out under different conditions of the cutting process recommend taking the value m≥3. If the number of thermo EMF values obtained - j corresponding to the condition (E (i-1) - Ei) ≤ΔE is greater than or equal to the quantity - m, (where, m = 3), then this value is taken as the break point, to assign the maximum cutting speed (Vjmax) for this cutting process condition. Further, the computer determines the number of revolutions of the machine spindle corresponding to this value-nj for a given diameter of the workpiece-D and the spindle speed of the CNC machine is changed.

Thus, the automatic control system on CNC machines provides the choice of the maximum cutting speed, which provides an increase in the productivity of the machining process.

V. EXPERIMENTAL RESULTS

In the experimental studies, various materials were used. The material of the cutting tool was - P18. The cutting depth t = 1 mm; Geometric parameters of the tool: the front angle γ = 8, the main rear angle α = 8, the angles in the plan φ = φ1 = 45, the angle of inclination of the cutting edge λ = 0. Longitudinal turning on the lathe with MNC 16К20Ф3С32. These parameters of the cutting mode correspond to semi-finished and finishing turning, which is typical for processing on CNC machines As a result of experimental studies for different processing conditions, the following maximum cutting speed values are obtained:

1. Material of the workpiece Steel 3Sp; S = 0.18 mm / vol.
At E4 = 3.5 mV: Vmax = 36 m / min. T = 95 min, hz = 1.5 mm.
2. Material of the workpiece Steel 3Sp; S = 0.08 mm / vol.
At E3 = 3.8 mV: Vmax = 60 m / min. T = 130 min, hz = 0.45 mm.
3. Material of workpiece Steel 5; S = 0.4 mm / vol.
At E3 = 3.8 mV: Vmax = 28 m / min, T = 120 min, hz = 0.55 mm.
4. Material of workpiece Steel 5; S = 0.2 mm / vol.
At E4 = 4.0 mV: Vmax = 60 m / min, T = 100 min, hz = 0.7 mm.
5. Material of the workpiece Steel 40X; S = 0.25 mm / vol.
At E5 = 2.7 mV: Vmax = 36 m / min., T = 70 min, hz = 0.8 mm.

all the experimental studies carried out, with an increase in the cutting speed more than Vmax, the value of the thermal EMF hardly increases, but wear increases and the tool's resistance sharply decreases. Thus, the selected cutting speed Vmax, other things being equal, is the maximum for the initial values of the processing conditions.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 10 , October 2018

VI. CONCLUSION AND FUTURE WORK

Thus, the practical implementation in the production of automatic control systems for cutting modes to ensure the reliability of the functioning of technological processes of machining on CNC machines in flexible production systems. It will allow to combine the principles of processing, taking into account the individuality of the cutting process of each specific work piece, the seriality of the products, diagnose tool wear, the quality of the treated surface, develop methods for rapid optimization of cutting modes, i.e. to investigate a set of indicators of workability of both existing and new materials.

The developed algorithms and software for determining the maximum cutting speed, in the form of a set of subprograms, it is necessary to equip CNC machines. This allows to improve the structure of the hardware implementation of the automatic control system by the process on CNC machines operating in flexible production systems and as a result the following technical and economic indicators will be obtained: - the productivity of cutting processing will increase more than 2-3 times; - reduce the technological complexity of manufacturing parts; - the consumption of cutting tools will decrease by 40-60%; - increase reliability, stability of machining on CNC machines in flexible production systems.

REFERENCES

[1] AA Korotysh and others. Multiparametric control of the cutting process // Electronic scientific and technical journal "Modern scientific research and innovations" 2013, No. 2
[2] VM Karpov CUTTING TEMP - a diagnostic indication of the state of the tool. In 2 parts. MSTU them. NE Bauman. Moscow. 2000
[3] The theory of automatic control of technological processes: Yu. V. Petrakov, OI Drachev. - Stary Oskol: TNT, 2013. - 352 sec.
[4] Nikitina LG Methods of measuring parts on CNC machine tools // Mechanical engineering and life safety, Moscow -2012. No. 3. Pp. 73-76.
[5] I.V. Lazarenko, A.V. Fedotov Active control system for the processing center. // Mechanical Engineering, Moscow, 2012. №12.C.21-25.
[6] SN Sharabura, VV Shevchenko System of adaptive control of the process of processing parts on CNC machines // Electronic scientific and technical journal "Modern scientific research and innovations" 2014, №6 P.1
[7] Ivaschenko AP Methods and means of monitoring the state of the cutting tool / / International Journal of Applied and Fundamental Research.-2013 №12-13 - p.393-396.