Creation of an automation system for engineering calculation of preparation for the production at high-technology enterprises of mechanical engineering

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Abstract: The article considers the creation of the automation system for labor-intensive engineering calculations, which is carried out by a technologist to prepare for work of metal-cutting equipment. This way allows to reduce the time for the process of technical preparation of production. All calculations are performed using modeling in the program Borland Delphi 7. The main technical parameters of the technological preparation of production are marked. The information model of the cutting system is designed. The modeling algorithm for selecting optimal parameters for the operation of the equipment is made. A graphical interface has been created for sequential selection of equipment and production tooling for operation of the technological process. Consequently, the program allows to automate the creation and processing of technological documentation, and reduce the time for designing technological processes in enterprises. Also, the developed interface can be used in the educational process to study production tasks.

1. Introduction
A problem of automation of technological preparation of production exists in the conditions of the development of high-tech engineering production in Russia, especially designing technological processes, operation development, tooling selection and calculation of cutting modes for process operations. It is necessary for solving this problem to automate the creation of technology for manufacturing products and calculations for the organization of work of metal cutting equipment.

There are many programs created to automate the work of a technologist and designer. All of them have a common problem: there is no situation accounting in a particular production. Necessity arises for long training and adaptation of personnel, adjusting the program for the conditions of the enterprise. Therefore, it is important to create a software from scratch, and taking into account all the features of technological equipment and organization of the production process.

2. Research
The purpose of our research was the creation of a program for the automated design of technological processes and calculation of cutting regimes of technological process. Modern metal cutting machining centers were selected for the research.

Objectives of the research:
1. Automation of designing of technological process of product manufacturing.
2. Automation of technological calculations with optimization of cutting modes.
3. Results and discussion

Research methods: analytic method and model analysis.

Description of the experiment. An experimental site equipped with high-tech equipment was created for the experiment [3]. Devices having computer numerical control of type WinNC: lathe with EMCO Turn 55 and milling Mill 155 became the technical means of carrying out the experiment. The following program software was used: Borland Delphi, CAD; systems: Kompas-3D, SolidWorks, Pro-Engineer, the program of monitoring and diagnostics, simulation and editing of processing of a detail, etc.

![Figure 1. Information model of the cutting system.](image1)

Initially, we marked the main technical parameters that affect the cutting system: machine, device, cutting tool, workpiece. After that the information model of the cutting system was compiled that shown in Figure 1. Next, we compiled an algorithm for calculating the cutting modes for the operations of the technological process shown in Figure 2.

![Figure 2. The structure of the modeling algorithm.](image2)
The algorithm includes the following components: the statement of the problem, nomination and testing of hypothesis, formalization of the initial information, generating of alternative variants, expert evaluation and screening out of rough variants, construction of a mathematical model, formation of a modeling algorithm, optimization of the solution of a mathematical model, visualization of the task solution results, the analysis of the results, the variation of the initial data and models in a series of successive iterations of the research process, the creation of a database and a number of other steps.

Next, we made a graphical interface for modeling and calculating the optimal parameters of the cutting process, that is shown in Figure 3. This interface was made in the program of Borland Delphi.

![Figure 3. The interface for calculating the operating modes of equipment.](image)

This is due to the fact that, the choice of optimal processing modes is a very laborious and complex task, because of the following reasons:
1) the efficiency of the manufacturing process of parts on metal cutting machines depends on many interrelated factors such as processing modes, tool geometric parameters and its wear, the properties of the workpiece material and tool material, the stiffness of the SPID system (the abbreviation in Russian that means machine, device, tool, part) etc. [4].

2) there is a wide variety of factors that affect the cutting process ambiguously, i.e. some of them are contradictory from the point of view of optimality of efficiency criteria such as, for example, roughness, accuracy, productivity, cost price, etc.;

3) most of the parameters of the cutting modes specified in the reference books and various normative materials have a certain range, which is not optimal, and has a recommendatory character. [5,6];

4) many dependencies of the cutting process are non-linear. Dependence of the wear rate of the tool on the cutting speed, which has a pronounced nonmonotonic character with a very narrow range of optimum cutting speeds, is an example for this. [2];

5) The tasks of optimizing the cutting process are multiparameter, multicriteria.

But, at the same time, among the set of acceptable variants of machining of parts, there is an optimal variant, estimated by singular criteria and as well as by additive criteria of efficiency [1,2]. Finding the optimal variant of the treatment process by experimental means is a complex and time-
consuming task that requires a lot of money and time. To reduce the labour intensity and exclude expensive field studies, it is necessary to use computers and optimization methods that exclude a complete enumeration of the set of admissible variants.

A certain set of initial parameters is shown on the graphic form: cutting modes; the workpiece material; geometric parameters of tools; type of processing, etc. An individual composition of parameters for solving a specific task will be chosen from the set of initial parameters.

Output data include the following: calculation results of $R_z$, $P$, $s$ and others; dependency tables $R_z=f(r,v,t,\varphi)$, $P=f(T,D,s,t,n)$; the panel of graphical plotting of diagrams according to the table data; optimal values of the parameters. The plotting of diagrams is accomplish in accordance with indicated their type and quantity.

The studying mathematical models are presented in the form of a set of multiparameter nonlinear dependencies and functions. These functions are stored in the database and used to form the optimization model and present them in the required format. A "coordinate descent method" for multidimensional functions [2], and heuristic algorithms are used to find the optimal value of the efficiency criterion. Limitations are valid parameter values. Optimization is accomplished out by variation these parameters in the specified boundary ranges. The optimal solution is given in the form of refined values of the parameters where the objective function takes the extremal value $F_{\text{min}}$ (or $F_{\text{max}}$) for a given efficiency criterion.

Figure 3 shows the data of determining the optimal parameters of the cutting mode according to the roughness criteria $R_z$ and the productivity $P$. We express the dependence of the roughness and productivity criteria on the cutting modes in the following form [4]:

$R_z = \frac{0.4}{8r} \sqrt{\frac{8.25 \cdot r^{0.15} \cdot V^{0.3} \cdot \sin \varphi^{0.4}}{t^{0.3}}},$  

(1)

$r$ – radius at the top of the lathe tool, mm; $V$ – cutting speed, m/min; $t$ – depth of cut, mm; $\varphi$ – the main angle in the plan, deg.

$P = \frac{\pi \cdot D \cdot n \cdot t \cdot s}{1 + \frac{\tau_{ch}}{T}},$  

(2)

$D$ – workpiece diameter, mm; $n$ – rotation speed, rpm.; $t$ – depth of cut, mm.; $s$ – feed, mm/rev; $\tau_{ch}$ – tool change time, min; $T$ – withstandability of lathe tools, min.

The withstandability of lathe tools is determined by the following formula:

$T = \frac{C_v \cdot k_v}{v \cdot t^x \cdot s^y},$  

(3)

$v$ – cutting speed, m/min; $C_v$ – a constant value for determining the group of processed material; $k_v$ – a coefficient, depending on the properties of the processed material and the cutting tool, on its geometry, wear, and also on the lubricating-cooling liquid; $x,y$ – indexes of degree depending on tool properties and cutting conditions.

Substituting (3) into (2) and taking for the perturbing effect a change in the size of the allowance for a constant $t$, we obtain the objective function:

$P = \frac{\pi \cdot D \cdot n \cdot t \cdot s}{1 + \frac{\tau_{ch} \cdot t^x \cdot s^y \cdot v}{C_v \cdot k_v}},$  

(4)
Then the databases for each parameter of the cutting system were created by us. Figure 4 shows a database for selecting and adding a tool. In this database you can select the tool by material, by typical size and by number. The database provides technical characteristics, markings and other parameters necessary for the technical calculation of the operation of the technical process.

**Figure 4.** The database of cutting tools.

Figure 5 shows the database of workshop equipment.

**Figure 5.** The database of metal cutting tools.
The database is intended for entering technical characteristics of metal-cutting machine tools in the database of the enterprise. It is possible in the database to constantly make changes. During purchasing new equipment, it is entered in the database. During it is written off or out of order, it is deleted from the database.

4. Conclusion
The created program allows doing the following:
1. Automating the execution of technological documentation and simplify the calculations for technological operations;
2. Reducing the design time of technological processes;
3. Using the developed interface in the learning process to study production tasks.

The result of our work is the developed interface for calculating cutting modes for metal cutting machines and a catalog in the form of a database of cutting tools and equipment passports.

References
[1] Grubiy S V 2014 Optimization of the Machining Process and Control of the Operating Parameters (Moscow: Mechanical engineering) 422 p
[2] Makarov A D 1976 Optimization of Cutting Processes (Moscow: Mechanical engineering) 278p
[3] Savelyeva N N 2017 Schooling of Future Bachelors-Oil Workers for Professional Work in High-Tech Enterprises (Tyumen) 122 p
[4] Savelyeva N N, Bogolubova M N and Proskuryakov P U 2012 Design-technological schooling of engineering students on the basis of electronic educational resources Fundamental Research 6-2 (Moscow) pp 388-91
[4] 1985 Handbook of the Technologist-Mechanical Engineer ed Kosilova A G and Mesheryakova R K (Moscow: Mechanical engineering)
[5] Wu B Manufacturing Systems Design & Analysis: Context and Techniques 2/e (UK: Chapman & Hall)
[6] Sandvik Coromant 2015 Common Turning Processes Digital Library 18 p
[7] Vinesh Raja and Kiran J Fernandes 2008 Reverse Engineering – an Industrial Perspective (London: Springer)