Method for automation of tool preproduction

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Abstract. The primary objective of tool production is a creation or selection of such tool design which could make it possible to secure high process efficiency, tool availability as well as a quality of received surfaces with minimum means and resources spent on it. It takes much time of application people, being engaged in tool preparation, to make a correct selection of the appropriate tool among the set of variants. Program software has been developed to solve the problem, which helps to create, systematize and carry out a comparative analysis of tool design to identify the rational variant under given production conditions. The literature indicates that systematization and selection of the tool rational design has been carried out in accordance with the developed modeling technology and comparative design analysis. Software application makes it possible to reduce the period of design by 80….85% and obtain a significant annual saving.

1. Introduction
It is typical of some state-of-the-art machine building enterprises to increase production of a set of products that implies not only realization of the manufacturing process but its preproduction as well. One of the integral parts of the machining process is fitting it out with cutting tools. Tool preparation for part cutting includes the following steps: tool designing, fabrication, selection of the most efficient variant for the manufacturing process, as well as a selection of the optimum machining mode and tool geometry [1 – 9].

The primary objective of tool production is a creation or selection of such tool design which could make it possible to provide high process efficiency, tool availability as well as a quality of received surfaces with minimum means and resources spent on it. Design of special cutting tool depends upon the machining conditions, but it is a time-consuming operation which makes an increase in design value. It takes much time of application people, being engaged in tool preparation, to make a correct selection of the appropriate tool under given conditions and among the set of variants. This has to do with the fact that the set of products, offered by some manufacturers, are widely presented and new designs are permanently developed at present.

One of the tracks of a solution of the problem is to create a computer-aided system (here and after CAD) with a storability of cutting tool designs and their selection readily available for the working conditions. Today’s there is a number of software and IMS (information system) which realize a possibility to select a cutting tool for a machining procedure [10 – 14]. But in selecting a tool, one is generally guided in these programs by the quality of machined surfaces and does not take into account process efficiency, tool operability and feasibility study.

Thereby, the research objective is a software development that makes it possible to systematize
information of cutting tool design and to carry out their comparative analysis in order to identify an efficient option under given production conditions.

2. Theoretical study

For further aim to be achieved, the authors have offered some methods of modeling, computer-aided designing, systematization and appraisal of the design concept of a cutting tool assembly to realize the cutting process.

Modeling of a cutting tool assembly is developed by example of milling cutters based on graph theory. The technique makes it possible to carry out analysis and synthesis of a design during the tool preparation [1].

To select the efficient tool design in the preparation of the machining process, the method of comparative multiple-factor analysis of tool design has been developed with allowance for variable production conditions. Thus it makes possible to optimize and computerize the tool selection procedure for the agreed operational conditions [1].

The definition of the rational option of the machining process is based on criterion findings, which, this way or another, exert influence on the production of parts in every case study [2]. These criteria are to be denoted by \( K \), and the range of process criteria can be represented in the form of \( K = \{ K_j, K_2, K_3 \ldots K_j \} \), where \( j \) – index of the performance criterion.

A set of parameters of the process is denoted by \( Y \), then the range of comparable engineering solutions including certain menu (set of parameters) can be represented in the form of \( Y = \{ Y_1, Y_2, Y_3 \ldots Y_i \} \), where \( i \) – index of record with a set of parameters.

Each of the criteria has a set of parameters \( t = \{ t_1, t_2, t_3 \ldots t_m \} \) influencing its value. The influence of the parameters on the criterion value is expressed in terms of:

\[
K = f (\{ t_m \})
\]  

(1)

And quantity and composition of parameters are to be defined for each production optimization case separately.

For the optimum process alternative to be identified, it is necessary to define the weighting criterion factor for each comparable case in terms of:

\[
q_i = \prod_{j=1}^{k} k_{ij},
\]

(2)

\( q_i \) – weighting criterion factor for \( i \) tool design; \( k_{ij} \) – factor which depends on criteria and production conditions.

\[
k_{ij} = \frac{a_{ij}}{a_{ij\max}} \lambda_j,
\]

(3)

\( a_{ij} \) – value which accepts \( j \) criterion for \( i \) tool design; \( a_{ij\max} \) – maximum value, \( a_{ij} \); \( \lambda_j \) – value factor of the \( j \) criterion.

Criterion value factor \( \lambda \) is set to intensify the importance (value) of one parameter or a few parameters of manufacturing efficiency.

The battery of value factors for each criterion is to be specified by production conditions. At this value factor of criterion significance, \( \lambda \) is rationally to be taken in the range from 1 to 5, but it can be increased according to the specifics of the production under consideration.

For example, there are five dedicated criteria in the researched process which determine the production efficiency: Making the production conditions, it is specified that the criterion values of \( K_1 \) and \( K_2 \) are necessitated to be high, criterion \( K_3 \) is considered to be unimportant, but criteria \( K_4 \) and \( K_5 \) should be medium. Then criterion significance factors can be set as follows: for \( K_1 \) and \( K_2 – \lambda_1 = \lambda_2 = 5 \); for \( K_3 – \lambda_3 = 1 \); for \( K_4 \) and \( K_5 – \lambda_4 = \lambda_5 = 2.5 \). Production conditions are subject to
variation, then different values of \( \lambda \) factor are to be set.

The results of the calculation of the weighting criterion factor are to be reduced to the resultant vector:

\[
q(q_j) = [q_1; q_2; \ldots; q_n]
\]  

(4)

The largest value of the weighting criterion factor is evidence of a greater rationality of the design.

A number of significant process criteria can be proposed for the production line: tool availability, process efficiency, quality of the machined surface and affordability.

Each parameter is calculated on the basis of mathematical models received as a result of test data handling and depends on the tool strength characteristics, strength of work material, machining mode, tool geometry as well as economic components of the cutting process.

3. Automation of tool preproduction

The practical application of presented methods are actualized in the bundled software and intended for systematization and a rational selection of the tool design taking into account variable conditions of the machining process (by example of milling tool). The complex consists of two interconnected modules.

The first software module (fig. 1) is intended for describing the design of the cutting tool assembly in a dialog mode. The module is oriented to systematize an available range of assembled tools, synthesis and analysis of new designs.

The module consists of a dialog box with a main menu that makes it possible to carry out operations dedicated to define an optimum tool design, to make reports containing information of designs available, search for information by parameters to be set by a user and to type it out. There is a
possibility to display information. Below there is a navigator that enables records of travel, edit, add and delete data.

The basic software field allows entering information about cutting and body-part materials, design, cutting part profile, parameters of cutting and body parts, availability of abrasion resistant coating and strengthening, presence of bolt, pin and edge fastenings on the chart, as well as tool functions and etc.

Data input is secured at the expense of information available in the dropdown list box, e.g. in order to select material for cutting part, suffice it to indicate a kind of tool material and then select its grade.

Software is provided with an information database that contains certain information about cutting tools. It includes physical-mechanical and strength properties of work and tool materials widely used in industry. Today, software database contains above 300 grades of tool material divided into 7 groups.

Describing a tool design in the software, first the user indicates the group of tool material in the section Material of Cutting Part (fig. 2) and then selects a material grade (fig. 3). The information of materials and their properties are hold in the specially created tables.

There is an opportunity for the user to indicate some additional parameters when making a description of tool design, e.g. it is possible to indicate a type of cutting components, a cost of one set and a number of regrinds. Press button + in the section “Material of Cutting Part”; there appears to be a relevant dialog box (fig. 4).

The program checks the filling in required fields after the information has been entered and saved by the user. Under the beneficial effect, the design data are to be automatically saved in the tables hidden from the user. A database is created on basis of data to be used for a comparative design analysis.

Searching for the optimum design, one should select item Data in the menu, then pt. Optimum Design, following which one can get a free access to the second software module as shown in Figure 5.

The second software module suggests machining material, calculation-making criteria and cutting modes in order to make a proper selection of the tool design. The calculation is carried out in terms of the comparative analysis and depends on the information entered. The result is displayed in the lower part of the dialog box in the form of information in relation to an efficient option of the cutting tool design with indication of its number in the database, its cost and cutting part condition.
Furthermore, additional and previously accumulated data concerning edge-cutting machining of a
certain sort of machined materials can be set into the module. The information basis of calculation is
made in terms of a referral database of grades and properties of tool and structural materials. The
referral database can be edited and updated in case of fresh information arrival.

The theoretical calculation has been made with allowance for design laboriousness in order to
evaluate the cost effectiveness of the software application in developing the process.

![Software dialog box](image)

**Figure 5.** A software dialog box to select an efficient cutting tool design.

Direct saving rate of a decrease in labor intensive designing and selection of a cutting tool during
application of software can be worked out by:

\[
\Delta D_3 = \sum_{n=1}^{n} (C_1 M_1 - C_2 M_2)
\]

(5)

\(C_1, C_2\) – data processing cost per unit before and after implementation of the developed software, $;
\(M_1, M_2\) – annual information volume of the processing task before and after CAD implementation; \(n\) –
number of interrelated tasks.

For example, a number of process tasks per year to select a cutting tool will be 3000 units. Without
the use of CAD, selection of an optimum cutting tool design with the help of various methods will
take 2 hours on average (this value has been figured out with the help of chronometer, monitoring the
execution of one task to select a tool by comparative analysis).

Application of the developed software presented above, makes it possible to decrease the time up to
0.3 h (the value has been figured out with the help of monitoring a task execution of tool selection by
using the software, adjusted for expenditure of time for the initial data input and reckoning).

Thus, the annual information volume will make: \(M_1 = 6000\) h/year; \(M_2 = 900\) h/year.

Data processing cost per unit without CAD is equal to hourly wage rate of a worker that makes
about 8 $/h. Using CAD, it is advisable to take account of software cost and their payback. The cost of
the software for data base formation and comparative analysis comes to about 1000 $ and payback is
within one year. Thus, data processing cost per unit goes up by 0.33 $: \(C_1 = 8\) $/h; \(C_2 = 8.33\) $/h.

Taking into account the fact that the number of interrelated tasks is equal unity, there is a saving
rate:
\[ \Delta D_S = 40503 \text{ S/year} \] (6)

4. Conclusions
The automated system presented makes it possible to increase the efficiency of the design, to evaluate some different cutting tool designs subject to production conditions, to cut production costs. The theoretical calculation of preproduction of economic parts shows that the time to make selection of a regular-style design of cutting tool under the given production conditions can be decreased with application of the software by approximately 80....85%, making a significant affordability.

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