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# **Methods of Automating Process Development of Control Programs For CNC Machines Modern CAM - Systems**

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**ABSTRACT:** The article discusses the methods of automating the development process of modern computer-aided design control programs for machine tools with numerical control. The possibility of using control programs during post processing is shown. The software components of the design and technological preparation of production are presented. A three-dimensional model was post-processed and control commands were compiled in the G-code format. A post-processing method is provided, which provides an effective opportunity to include in the control program CALS-cycles of CNC machine tools.

**KEY WORDS:** G-code, STL format, software components, preproduction automation, computer-aided design systems, control programs, integrated system, automated processing systems.

## **I. INTRODUCTION**

Modern production relies heavily on the use of CNC machines. The machines themselves are becoming more complex, becoming more intelligent. However, their efficient operation requires effective management. Increased competition and the market demand for complex products make enterprises think about the integrated automation of pre-production and production itself. In this formulation, the stage of developing control programs is no longer perceived as an autonomous task, but must be linked to other stages of the design and technological preparation of production.

The efficiency of CNC machines is primarily determined by the timely provision of their control programs. Preparation of control programs is one of the most responsible and labour-intensive stages of technological preparation of production for CNC machines. The problem is especially complicated by the manual preparation of control programs for the processing of contour blanks. Therefore, it is becoming increasingly important to use for the development of control programs of various computer-aided program preparations (SAP) systems, dramatically increasing their quality and shortening the time taken for preparation of production.

Modern production is characterized by the presence of a large number of CNC machines from different manufacturers. Each machine is focused on solving problems of a specific circle and is designed to work with control programs written in a special format. Most Computer Aided Manipulation (CAM-system) / computer-aided design (CAD) systems used in production create a file with a control program in an invariant format, such as APT or CLDATA, that is not tied to any particular CNC machine model. To translate an invariant control program into a program in the codes of a particular CNC system, special interpreters, called postprocessors, are used. Along with universal postprocessors provided by CAM-systems, programmers often write their own post-processors, focused on specific, often specific modes of operation of the machine, taking into account the features of a particular processing. As a result, with the growth of production and the expansion of the park of CNC machines, the number of postprocessors used also increases, which, in turn, requires some systematization for convenience and simplification of the process of post processing control programs in the invariant code. In the software market, many CAM systems offer their solutions to an emerging problem. But often they are rigidly tied to the basic CAM-system, which is especially inconvenient when using multiple systems in one enterprise. In this regard, there is a need for an autonomous means of automatic preparation of control programs. A software module was created specifically for the solution of the listed tasks - the manager of the preparation of control programs (PCP). Its main purpose is to automate the process of post-processing of invariant control programs and the organization of the library of post-processors available in the enterprise.

PCP allows you to quickly post process one or several invariant control program files by the specified postprocessor, which makes it possible to speed up the process of preparing control programs and reduce the number of errors associated with the incorrect selection of the postprocessor. Such errors lead to the appearance of defects in the final product and are very poorly tracked, so it is important to minimize their number already at the stage of generating the control program.

**II. MATERIAL AND METHODS**

The purpose of the development is the development of control programs for CNC machines of modern CAM - systems. During post-processing and development of control programs, the following tasks were performed:

1. Ensuring the import/export of geometric models in the grid view with a given accuracy.
2. Working out mathematical methods for post-processing the geometry of models and forming a discrete, three-dimensional type of models with a given accuracy.
3. Development of tools for modeling processes and carrying out numerical engineering calculations.
4. Preparation of the software environment for compiling control commands for promising modern CAM systems.

To achieve the objectives, the PCP was developed, which is an application for the MS Windows operating system, built on the basis of the Windows API without using additional software libraries. For graphics, the OpenGL standard is used. All geometry is represented by double-precision floating point numbers of 8 bytes per number, which makes it possible to programmatically not to limit the accuracy. The total number of objects processed at the same time is limited only by the amount of computing resources used and the size of the address space allocated by the operating system - 3 gigabytes for 32/64-bit applications.

The PCP is built on a modular basis using an object-oriented approach. The structure of the PCP contains the core of the system, the database of objects, the user interface, the calculated subroutines. Polymorphism incorporated in the design of the system allows you to work invariantly with different types of objects: c loaded models in the form of grids, with parametrized internal objects, discrete objects of a three-dimensional view. Using the component approach in the development of PCP allows you to extend the functionality of the system by integrating new code without rebuilding the main modules of the entire system. [3].

To export models from CAM systems, the G-code format are used (Fig. 1). Loaded objects are ordered in a hierarchical structure.

**Input/Output**

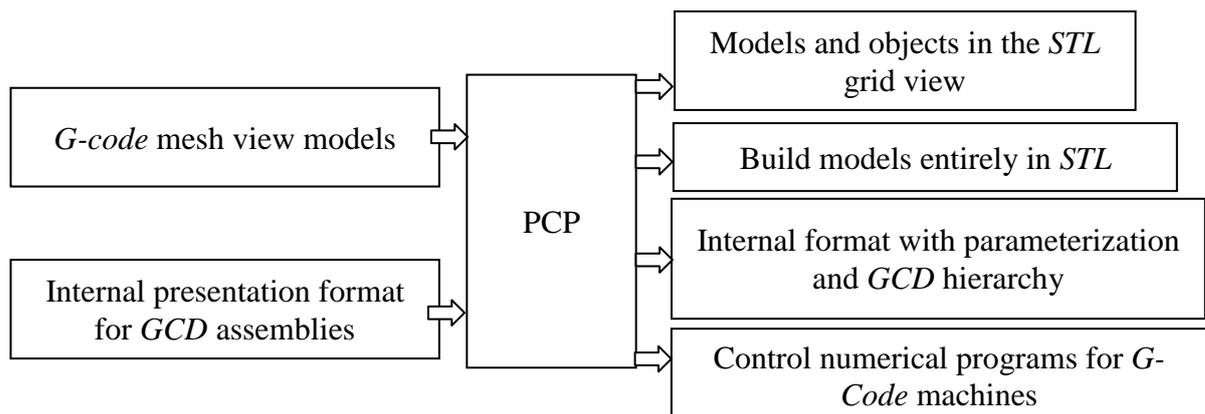


Figure 1. The block diagram of the organization of the management of input-output information in PCP

In the case of mathematical support of the PCP, programs are used that form the structure of the designed system, represented as a multidimensional object, at the input of which a vector of input variables  $\vec{x}(\tau)$ :

$$\vec{x}(\tau)=[x_1(\tau),x_2(\tau),\dots,x_n(\tau)],$$

where  $x_1(\tau),x_2(\tau),\dots,x_n(\tau)$ - vector components  $\vec{x}(\tau)$ , they characterize, first of all, the full set of properties of the blanks and semi-finished products (dimensions and their deviations, surface roughness and microhardness, structural parameters, etc.) used in this object.

Output Variables describes a vector  $\vec{y}(\tau)$ :

$$\vec{y}(\tau)=[y_1(\tau),y_2(\tau),\dots,y_n(\tau)],$$



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where  $y_1(\tau), [y]_2(\tau), \dots, [y]_n(\tau)$ - vector components  $y^{\sim}(\tau)$ , they characterize the properties of the finished part (dimensional accuracy, shape and relative position of surfaces, surface roughness, etc.).

Components of both the input and output vectors can be not only the structural and technological properties of work pieces, parts, assembly units, but also the values reflecting the technical and economic indicators of the PCP.

The parameters characterizing the conditions of the flow of PCP, describe the vector  $z^{\sim}(\tau)$ :

$$z^{\sim}(\tau)=[z_1(\tau), z_2(\tau), \dots, z_n(\tau)],$$

where  $z_1(\tau), [z]_2(\tau), \dots, z_n(\tau)$ - vector components  $z^{\sim}(\tau)$ , these are, for example, temperature, pressure, flow, rotational speed, as well as factors that have a destabilizing effect on the course of the PCP.

The dimension of the vectors  $x^{\sim}(\tau), y^{\sim}(\tau), z^{\sim}(\tau)$  for real processes is very large, and it is impossible to take into account all their components, some of the components are considered as random functions.

Information is exchanged between the main library module and the postprocessor through temporary files that are created in the TEMP\_CNC folder in the system temporary files directory. In the TEMP\_CNC folder, a folder of the current session is created, in the name of which there is a unique GUID. The control program conversion is started via the "NC program toolbar" command. During the program conversion, the following files are created in the temporary folder:

- input.tmp - a temporary file with the source text of the control program in an intermediate language;
- output.tmp - a temporary file with the program text in the language of a specific NC system, obtained as a result of the postprocessor operation;
- path.tmp - a temporary file containing a description of the tool paths inside the machine cycles.

In the diagram, the numbers indicate the following sequence of actions:

- 1 - Generation of a control program in the intermediate language codes and writing this program to disk in a temporary file input.tmp.
  - 2 - Run the python.exe process using the Windows API CreateProcess function. The path to the input.tmp file is passed as a command line parameter.
  - 3 - Execution by the Python interpreter execution of the post-processor script that reads the file input.tmp from the disk.
  - 4 - Creating new frames in the execution process to the postprocessors of the input.tmp file, new program frames are created, which are written to disk in the output.tmp file.
  - 5 - If the original NC program contains machine cycles described in intermediate language and if the postprocessor implements the toolpath calculation for these cycles, a path.tmp file is created, which displays the tool path within the cycles.
  - 6 - The NC module waits for the NC module to wait for completion of the python.exe process using the WaitForSingleObject function (pi.hProcess, 10000) during the postprocessor execution time, where pi is the PROCESS\_INFORMATION structure. The maximum wait time is 10 seconds. If during this time the process has not been completed, then an error about timeout is issued. The need to wait for the completion of the process is caused by the fact that the file output.tmp is a shared resource, and it must have separate access from the postprocessor and the rtw module of the library.
  - 7 - output of the program to the properties panel after the library has finished reading the file output.tmp.
  - 8 - Read the path.tmp file and is recognized by the library to get the trajectory inside the machine cycles.
- To transmit messages from the postprocessor, the CNC module uses the standard buffer stdout. If the program is successfully converted, the postprocessor displays an OK message; in case of errors, stdout displays error messages. Through stdout, both the errors generated by the postprocessor and the errors generated by the python.exe interpreter are received.

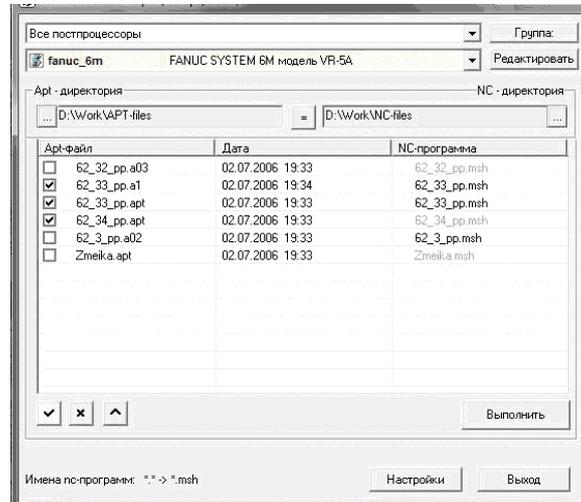


Figure 2. The main window of the program PCP

The PCP provides the technologist with the opportunity to choose the directories where the control programs generated by the postprocessor will be placed in accordance with the requirements of his enterprise. The process of generating control programs is visually displayed on the screen, informing the user about how much time is left until the end of the operation (Fig. 2).

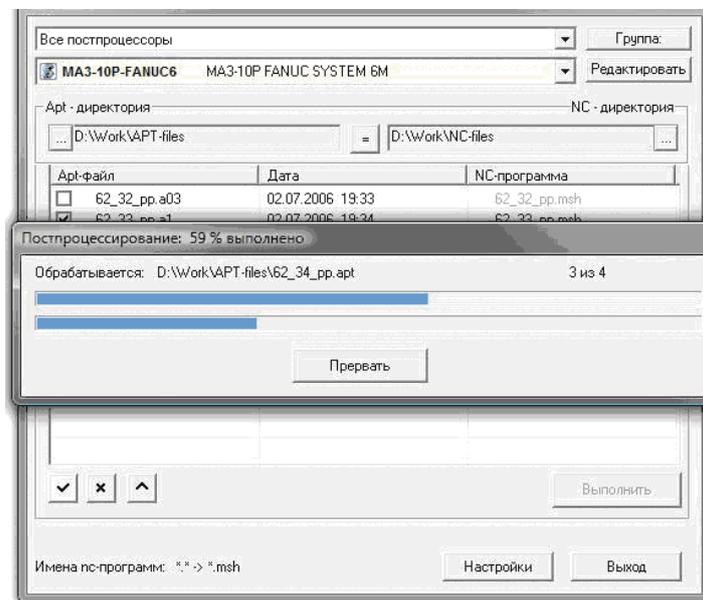


Figure 3. Post processing window of control programs for CNC machines

Enterprises using CNC equipment, as a rule, have their own set of postprocessors, each of which is designed for a specific type of machine or type of processing. PCP allows you to create a library of enterprise postprocessors, which helps to quickly select the right interpreter from the available ones, as well as streamline postprocessors by machine type, processing type, frequency of use, or any other criterion (Fig. 3).

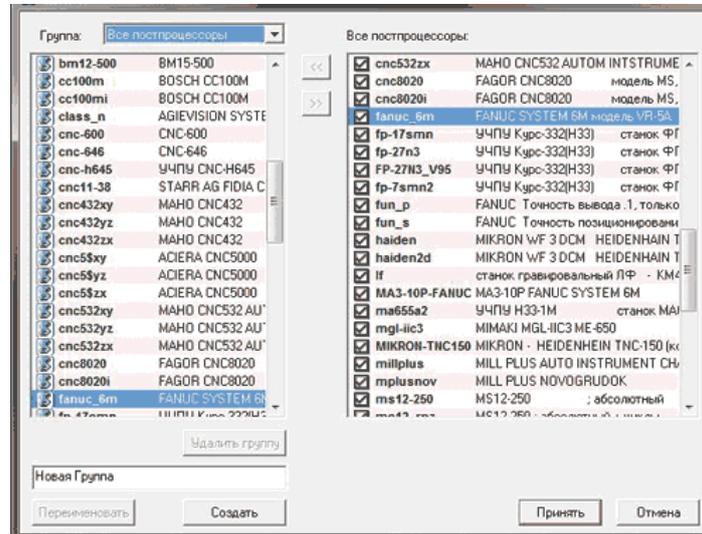


Figure4. Postprocessor accounting library window

The library provides the ability to combine postprocessors into groups in accordance with the wishes of the technologist and the requirements of a particular technological process used in production. Most CNC systems are configured to work with control program files whose names correspond to a specific format. Usually restrictions are imposed on file extensions with a control program. The manager of the preparation of control programs allows you to set the rules for generating the extensions of the generated files (Fig. 4). In addition to the registered extensions, the technologist can specify its own extension for files or specify it using the postprocessor.

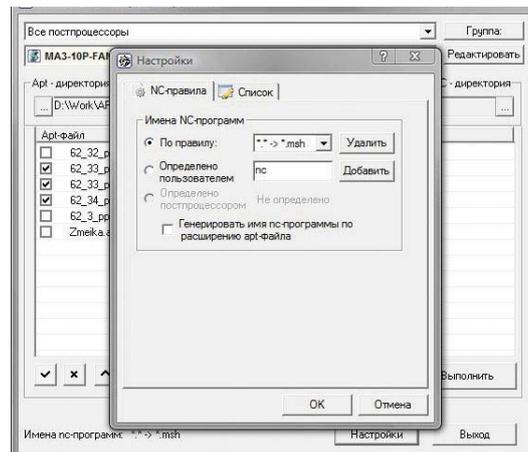


Figure5. The window of rules for the formation of names of control programs

In the course of work, the technologist may need to change something in the code of the current postprocessor or in the text of the control program. To debug code on the fly, the manager of the preparation of control programs has its own built-in editor that allows you to make changes to the program code without leaving the manager (Fig. 5). For greater clarity, the editor has syntax highlighting of auxiliary words, variables, operators, macro functions, etc.

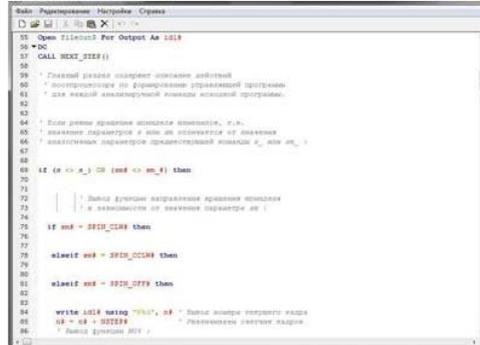


Figure 6. Postprocessor and control program editing window

## II.CONCLUSION AND FUTURE WORK

The development of a new postprocessor is carried out by the technologist himself in about 4 ... 8 hours, and without the services of a factory programmer, and even more so without the need to pay a dealer program for a foreign CAD/CAM system.

Using the developed methods and recommendations allows you to automate the process of creating control programs and preparing technical documentation, as well as reduce the requirements for qualifications of programmers, reduce the overall preparation time and improve the quality of UE.

The described features allow us to significantly automate the process of preparing control programs and organize a library of enterprise postprocessors.

Thus, using the module PCP with its ability to set user commands, it is possible to generate a postprocessor for any execution of the CNC system and thereby increase the efficiency of using the CAM module.

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