Automation of preproduction processes for high-precision small-sized parts on CNC machines

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Abstract. The theoretical basis of the processes of preparation for the production of high-precision small-sized parts of coaxial radio components on CNC machines allows you to supplement the existing CAD / CAE / CAM with fragments of algorithmizing. To integrate the stages of technological preparation for the production of high-precision small-sized parts of coaxial radio components on CNC machines, a study of the features of the production of parts and the standard functionality of CAM systems was carried out. A classification of these parts by the type of equipment, types, serial production, variable parameters within the type, materials, and tools has been developed. The possibilities of the extensibility of the functions of CAM systems, the existing methods of creating and verifying control programs are considered. An example of a successful expansion of the functionality of a standard CAM system in the radio-electronic industry is given - a module for increasing machining accuracy with a constant cutting mode by optimizing the mutual positioning of the tool and the workpiece. Requirements have been developed for the creation of a specialized combined method for verification of control programs using all existing verification capabilities and minimal use of debugging and verification directly on the machine with the maintenance of reference books of worked processing modes in which the number and size of burrs are minimal, as well as a library of control programs equipped with a search system for the parameters of the difference in the execution of parts.

1. Introduction

The theoretical basis of the processes for preparing the production of high-precision small-sized parts of coaxial radio components on CNC machines allows you to supplement the existing CAD / CAE / CAM with fragments of algorithms built on the basis of the main provisions of symbolic logic, which allows you to describe the designer's course of action within the framework of the concept of exact formalism and to draw up a model on its basis designer behavior within the constraints. Coaxial radio components are small, high-precision and are made of difficult-to-machine materials. The manufacturing precision reaches 7 quality standards, the overall dimensions are from 0.39 mm to 6 mm in diameter and up to 15 mm in length. The choice of materials for manufacturing is limited by technical requirements [1, 2]. For the production of internal and external conductors of sealed coaxial radio
components, alloy 29 NK is used to obtain coordinated thermal expansion coefficients of joints with S52-1 glass [3]. Conductors of leaking coaxial radio components are produced from beryllium bronze, less often brass, which is due to the springy properties of these materials, which are necessary for tight compression of the lamellas during assembly. During blade machining, burrs are formed on the surfaces of parts made of materials, which cannot be prevented. However, control of the parameters of burrs can significantly reduce the cost of removing them. To minimize the number and size of burrs, it is necessary to select the tool and modes of blade processing, and during processing, periodically measure both the overall dimensions and the burrs. This pre-production stage requires studying the recommended ranges for processing modes, setting specific values and testing on CNC machines. The test is carried out until the permissible number and size of burrs are obtained over a period of time that allows assessing the fulfillment of the requirement to ensure tool wear resistance and permissible parameters of burrs. The costs of creating control programs and full-scale tests can be reduced by using a number of measures to integrate the stages of pre-production and processing on CNC machines.

To carry out the integration of the stages of preparation for the production of parts on CNC machines, it is necessary to research the following issues [4-7]:
- classification of parts by type of equipment, types, serial production, variable parameters within the type, materials, tool;
- extensibility of the functionality of CAM systems;
- methods of verification of control programs;
- methods of creating control programs taking into account the classification of parts.

2. Classification of parts by type of equipment, serial production, standard designs with variable parameters, materials, tool

According to the inaccessibility of surfaces for deburring, the parts of coaxial radio components can be divided into two groups: internal conductors - parts that do not have internal hard-to-reach surfaces, external conductors - parts with internal hard-to-reach surfaces (grooves, pockets, grooves, etc.). Deburring of internal conductors (axles, bushings, etc.) is easily done in a tumbler, and a large number of larger burrs are acceptable. Deburring parts with hard-to-reach internal surfaces is challenging. Thermopulse deburring can be used to eliminate manual plumbing deburring [8, 9]. For high-quality thermal impulse deburring, it is necessary to control their size. The maximum size of the burr to remove depends on the type of material of the part, as well as on the presence of thin-walled elements. The ratio of the burr size to the minimum part thickness should not exceed 1: 4, otherwise thin-walled structural elements will be deformed due to annealing [10, 11].

By seriality, parts must be distinguished into serial and single orders of small volumes. One-time orders with the prospect of further serial production should be classified as serial. Verification of serial parts must be carried out taking into account ensuring the planned wear resistance of the tool; for one-time orders, it is enough to make sure that the tool retains its durability, the design dimensions and surface quality correspond to the drawing over several cycles of the control program.

By typical designs with the presence of various designs, parts can be grouped by the name of the part and the parameters of the designs, which are indicated in the drawing. The execution of parts can have different lengths, diameters, threads, end geometry, additional structural elements. For example, a part of the current lead of a radio frequency connector has 52 versions, which differ in the length of the current lead L, mm, the length of the overhang l, mm, and the presence of a radius at the end of the current lead. A fragment of a drawing of a part that has a multiple design, showing the difference in size, is shown in Figure 1.
Figure 1. Fragment of a drawing of a part that has a multiple design with a difference in the presence of a radius at the end of the current lead

A fragment of a drawing of a part having a multiple design, demonstrating the difference in geometric design elements, is shown in Figure 2.

Figure 2. Fragment of a drawing of a part having multiple execution with a difference in lengths L and l

The use of materials and tools from the list of acceptable substitutes also leads to the need to adjust the control program with its subsequent verification. For example, changing the diameter of the wire for the manufacture of the part shown in Figure 1 will change the depth of cut, the volume of material removed and the rate of consumption. Replacing a tool with an analogue acceptable according to the technological documentation, or even replacing a tool manufacturer with the same catalog number leads to the need to change the planned wear resistance and adjust the cutting conditions. Cutting data and tooling can also depend on the characteristics of specific equipment.

3. A set of functional capabilities of CAM systems and the possibility of their expansion
The variety of existing CAM systems has led to their specialization in areas of application and set of functionalities. Currently, the following classification of CAM systems is being considered: by the level of automation; by type of equipment; by the number of processing coordinates; by the method of forming the processing technology.

It is advisable to divide the level of automation into 4 classes:

- manual development, in which the writing of a program is carried out manually by a programmer-technologist using general-purpose text editors;
- automation of the function of calculating the coordinates of control points and constructing the tool path (for example - KOMPAS CNC);
- automation of functions for calculating cutting conditions and forming a processing technology with a preliminary manual formulation by a programmer-technologist of a processing scheme, equipment, tool, detailing an operation (for example - Gemma);
- automation of the function of creating a processing technology with the participation of a programmer-technologist (for example, SprutSAM).

By types of equipment, CAM systems are specialized for turning, milling, electrical discharge machining, machining centers, woodworking, engraving.

By the number of coordinates and the complexity of the operation performed, there are: 2, 2.5, 3, 4, 5-coordinate CAM systems.

By the method of forming the processing technology:
- Operation-based CAM systems require the user to follow numerous steps to select a machining strategy for each surface of a workpiece:
- Structural CAM systems use a set of processing elements to describe the finished part:
- Process-based CAM systems are typically used for programming similar processes and operations [12].

The choice of a CAM system is significantly limited by the compatibility with the CAD system used in the enterprise. Electronic models created with a CAD system must be readable by the CAM system. Modern CAM systems are modular [13, 14]. The composition of modules in terms of functionality and extensibility can be selected for the needs of a specific type of production. The presence of built-in programming tools makes it easier to customize the CAM system for the needs of production: describe postprocessors, connect additional modules created using high-level programming languages.

The presence of requirements for high accuracy, small size, and the absence of burrs on the parts of coaxial radio components leads to the need for a special setting of processing parameters and verification of control programs for their production using a full-scale experiment. When such tasks arise that cannot be formalized by typical means of general-purpose CAM systems, it becomes necessary to develop additional software products to automate and reduce the cost of compiling and verifying control programs.

4. Verification techniques for control programs
An important stage in the preparation of the control program is the verification and debugging procedures. Various options are also possible here.

The built-in ability to check the syntax and correct syntax errors of the control program by means of coding the control program with further debugging of the control program on the machine by processing test parts and correcting the identified inconsistencies is the simplest version of the verification method for control programs. This debugging technique is ineffective, time consuming, and distracting equipment from the production process.

Modern CAM systems usually have built-in verifiers, which provide the ability to graphically build and check the tool path according to the control program [15]. At a higher level, the processing is simulated using the control program with an indication of the errors that occur. In the extended verification mode, not only debugging is performed, including analysis and optimization of the control program. The use of such simulators to reproduce the results of the control program operation significantly increases the efficiency of the control program preparation.

However, the estimation of dimensions, the number of burrs throughout the entire life cycle of the tool, and their control are not covered by the existing functionality of CAM systems. Therefore, it is necessary to develop a specialized combined method for verification of control programs using all existing verification capabilities and minimal use of debugging and verification directly on the machine using reference books of worked out processing modes in which the number and size of burrs are minimal, as well as a library of control programs parameterized by classification parameters according to standard designs with the presence of various designs.
Possible strategies for developing control programs.
The following strategies of the enterprise in the field of automated development of control programs
in the technological preparation of production can be distinguished:
Manual creation of control programs directly on the machine.
Automated preparation of UE. for the implementation of which it may be necessary to purchase
computer equipment, a general-purpose CAM system or a specialized CAM system: purchase or
develop modules for expanding functionality; postprocessors for existing equipment.
Extended verification without performing.
Using simulators for verification:
- with the involvement of means of verification of the CAM system;
- with the involvement of specialized verifiers;
- using integrated analysis and optimization tools [16, 17] (for example, Tecnomatix).
When choosing the appropriate strategy, the following production conditions must be considered:
The serial production.
Urgency of the order.
Characteristics of the available equipment.
Available software.
The complexity of the product being developed.
Requirements for products being developed.
Personnel qualifications.

5. Examples of expanding the functionality of CAM systems.
Improving the machining accuracy with a constant cutting mode is possible by optimizing the mutual
positioning of the tool and workpiece. However, in the process of developing control programs for CNC
machine tools, the programmer-technologist is faced with a significant amount of calculations, among
which the calculation of the optimal positioning parameters plays a significant role [18]. Unfortunately,
such calculations, as a rule, are not automated by standard CAM systems [19, 20].

6. Conclusion
Investigation of the peculiarities of the production of parts for coaxial radio components and the
functionality of CAM systems made it possible to classify parts by the type of equipment, types, serial
production, variable parameters within the type, materials, tools. This allows one to develop
requirements for the creation of a specialized combined methodology for verifying control programs
using all existing verification capabilities and minimal use of debugging and verification directly on the
machine with maintaining reference books of worked processing modes in which the number and the
size of burrs are minimal, including control program libraries.

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