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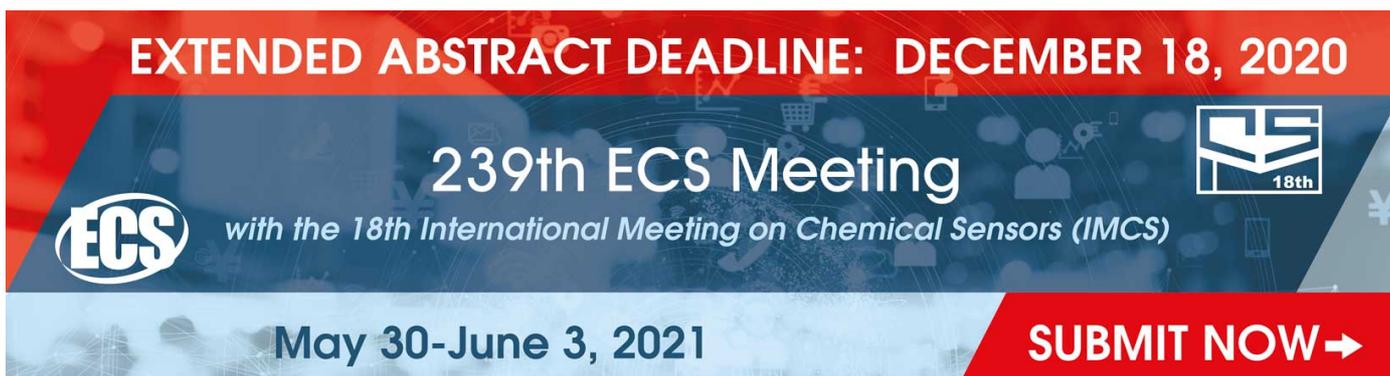
Practical aspects of constructing a specialized control system for compact machines

P A Nikishechkin*, I A Kovalev, O V Kazaryan and N S Grigorev

MSUT "STANKIN", Moscow, Russia

*pnikishechkin@gmail.com

Abstract. In the presented article is considered the task of constructing a specialized system for implementing numerical control of various compact machine solutions that allows to process wood or metal or create parts from model plastic based on additive technologies. The control system must be flexible and, by its principles of construction and programming, be close to classical CNC systems, but not possess excessive functionality and corresponding price. The development of such compact machine-tool solutions will make it possible to use them both for small productions and for training specialized specialists in working with numerical control systems and in their programming.

1.   Introduction

The level of automation of production processes is steadily increasing every year. Almost no modern engineering company can do without the use of metalworking machines equipped with modern systems of computer numerical control (CNC). Their use allows the production of parts for various industries, which are subject to stringent requirements for dimensional accuracy and tolerances. With the development of automation, the level of human participation for direct control of the processing is steadily decreasing, however, work on modern CNC machines requires a set of competencies for the operator related to both the general principles of working with machine tools and the ability to develop and adjust control programs, according to which processing operations will be performed. The functions of modern machines equipped with CNC systems are also expanding and supplemented, which increases the requirements for the training of highly qualified specialists and operators of such machines [1-4].

To expand the training opportunities for specialists, in particular, operators of CNC machine tools, control system emulators are often used. However, this may not be enough for the full development of the management process and mastering the necessary competencies [3,5-7].

The paper proposes the construction of a specialized system for the implementation of numerical control of various compact machine solutions (milling / engraving / laser), which allow to make wood or metal processing or create parts from model plastic based on additive technologies (3D printing). The control system must be flexible and, in its principles of construction and programming, be similar to classical CNC systems. The development of such compact machine-tool solutions will make it possible to use them both for small productions and for training specialized specialists in working with numerical control systems and in their programming. The basic requirements for the functionality of such a software and hardware complex are highlighted:
-   modular design of the hardware of a compact machine for the implementation of various types of processing.

- the principles of constructing a control system and its programming should be similar to CNC systems, but the system should not have excessive functionality.
- domestic kernel control system.
- cross-platform control system to support various hardware solutions and the ability to quickly change the system.
- low total cost of the hardware-software complex.

During the study, several Russian companies manufacturing compact machine solutions were analyzed. The main characteristics by which they were analyzed were: the manufacturer of the machine, the design of the machine, the parameters of the control system, the level of flexibility, the possibility of use in the educational process, the possibility of operational service and support, as well as price characteristics [8]. According to the results of the study, it was revealed that most of the available compact machines do not have a full-fledged modular design, which reduces the level of flexibility and does not allow their quick readjustment. Also, many compact machine complexes on the market are equipped with closed control systems, which also limits their ability to flexibly configure and provide prompt service support. Several manufacturers offer manual control machines or use simple control systems in their products, the programming of which differs from the development of programs for CNC systems. Such solutions can be used for small industries, but they are unsuitable for training specialized specialists. Thus, the development of a specialized universal system for control compact machine solutions is an urgent task [6,9-12].

2. General structural model for building a control system

The development of a specialized control system for compact machine solutions involves the adaptation and refinement of existing developments of the Department of Computer Control Systems (MSTU "STANKIN") regarding the development of the computing and control platform "AxiOMA Control". The controlling platform involves the use of a two-computer architecture of construction and implies the division into the kernel of the system and the terminal part. The kernel of the system is necessary for the implementation of all internal algorithms for calculating the trajectory, as well as for direct interaction with hardware components (servos, controllers, input / output modules). The terminal part interacts with the kernel of the system and is designed to implement man-machine interaction [5,6,13].

Using the basic computing and control platform to build a specialized control system for compact machines provides flexibility, import independence, as well as the ability to fully support and perform maintenance work on equipment from customers, in contrast to the approach in which software is purchased from various manufacturers, including those that are produced abroad. In the course of work, the main tasks for parameterization and refinement of the control system for its adaptation to control compact machine solutions were systematized:

- development of a structural model for constructing a control system for compact machine tools.
- parameterization of the basic modules of the system kernel.
- development of an additional module for controlling external devices.
- refinement of existing system configuration mechanisms for the possibility of parameterization of external devices.
- creation of algorithms integrated into the control system for the implementation of interaction with motion drives.
- development of specialized terminal solutions for the implementation of human-machine interaction.

To control compact machine solutions, it is not necessary to achieve high accuracy of axle movement and the use of expensive servo drives, which are usually equipped with modern machines, including those based on the "AxiOMA Control" control system. To drive the axes of compact machines, simpler servo drives with vector control in speed and torque can be used, for example, based on a hybrid stepper motor (SPS). This type of drive is not inferior in terms of interaction with them but compares favorably with them in terms of price characteristics. However, their control requires the development of an additional module for interaction with external devices via the CAN protocol. Despite the availability

of faster protocols, CAN technology has high reliability, and CAN-based drives are widely used to solve various automation problems, including the creation of compact machine solutions [14-15].

For building of the control system kernel for compact machine solutions, it is not necessary to use all the software modules of the kernel of the "AxiOMA Control" control platform, for example, the deep frame preview function, the kinematic transformation module, the five-coordinate processing module, etc. The listed modules are used to build complex CNC systems for controlling high-precision machine tools with complex kinematics [14]. Thanks to the modular construction of the "AxiOMA Control" control platform, it is possible to synthesize the necessary components to build both the kernel of the system and the terminal part. The structural diagram of the construction of an adapted and improved control system for compact machine complexes is shown in the figure (Figure 1).
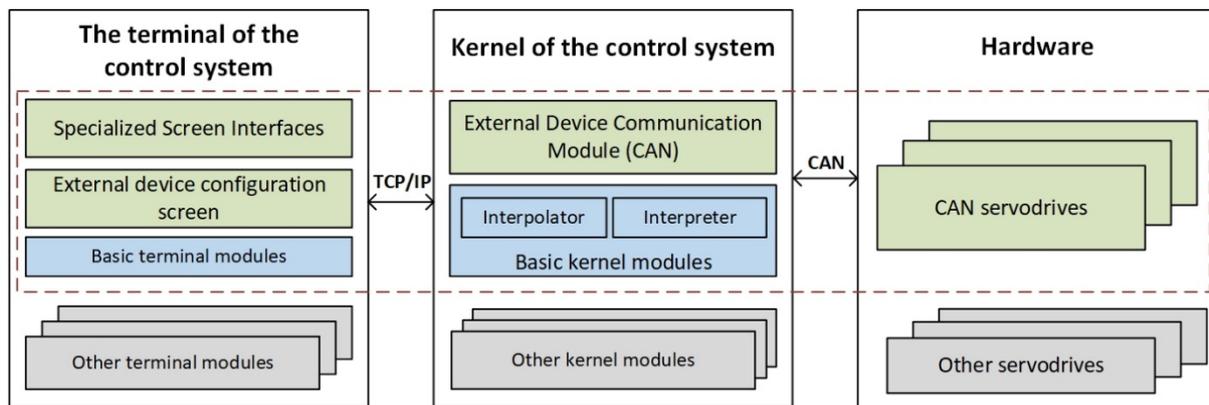
Figure 1. Structural model of building a control system.

The structural model displays a set of basic components and their interactions for constructing a control system for compact machine solutions. The basic components are the terminal part for man-machine interaction, the kernel of the system that performs calculations and control, as well as the hardware part in the form of servos.

To control compact machine solutions in the terminal part of the system, it is necessary to additionally develop several screen interfaces, as well as a screen for configuring external devices. To communicate with the kernel of the control system and solve communication problems, basic terminal modules are used, which are part of the "AxiOMA Control" control platform. Other terminal modules (software and hardware) are not required to solve the task. The terminal software can operate both on a classic PC and based on an industrial operator panel. The hardware terminal modules (operator panel, machine tool panel) are of industrial design for use in enterprises, and their use is not necessary for training specialists or control compact machines in small industries. Software terminal modules (a set of screens for displaying information about the operation of complex machine tools) are also redundant to solve the task of man-machine interaction with compact machine tools [5,13].

The kernel of the control system, which implements all the necessary calculations and controls the hardware, includes a set of basic modules necessary for parsing the control program received at the input and solving the geometric problem, i.e. generating the necessary movement commands. To interact with hardware - CAN servo drives with stepper motors, it is necessary to develop an additional module for interaction with external devices. Using the necessary basic modules and finalizing it as an add-in module allows you to compose the kernel of the control system in such a way that it is not overloaded with additional functionality and can work both on a PC and on a single board computer. The main condition for the kernel hardware platform is the use of the real-time operating system (RTOS) [14,16,17].

Thus, to build a control system for compact machine solutions that meets all the requirements, it is necessary to develop a number of modules in the terminal and the kernel of the system, and their synthesis with the selected set of basic modules of the "AxiOMA Control" control platform [14,18-20].

3.   Practical realization of modules for building a control system and its testing

As mentioned earlier, the construction of a control system involves the refinement of the necessary modules in the terminal and the kernel of the system and the development of their interaction with the necessary basic modules of the "AxiOMA Control" control platform. The developed specialized module in the kernel of the system is designed to implement the interaction and control of stepper motors via the CAN protocol, as well as transfer basic information about their work to the kernel of the control system. The basic computing modules of the kernel of the system, which perform the calculation of coordinates to implement the necessary trajectory of movement, are not tied to the specifics of a particular bus and use special interfaces to issue the necessary commands and receive data from the hardware [17,21]. To control external motors via the CAN interface, it is necessary to implement mechanisms for initializing such devices, requesting their basic states, and also issuing control commands to them. The sequence of basic steps for initializing CAN devices and interacting with them is shown in Figure 2.
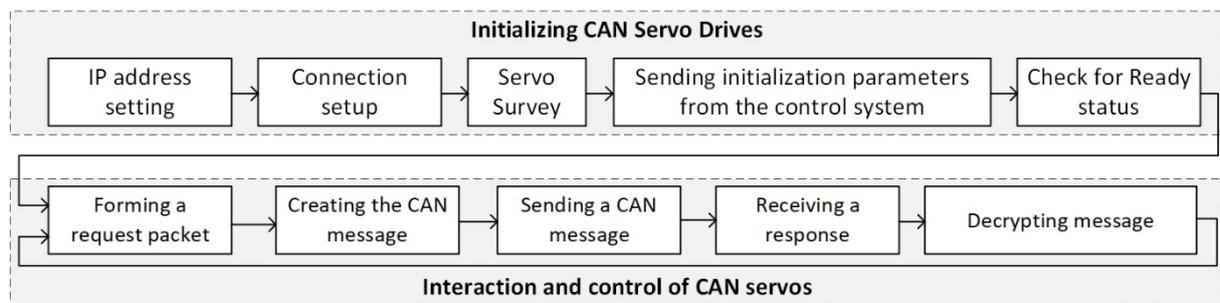

Figure 2. Stages of initialization and interaction with CAN servodrives.

Servo drives are initialized according to the following algorithm: setting the connection, checking the availability of motors, receiving initialization parameters from the control system, and checking that the servos are ready for operation. In the event of a successful initialization, the work can be continued, otherwise an error signal arrives. Request parameters from the servos and send commands in the following sequence: forming a request packet, creating the corresponding CAN message, sending a CAN message, receiving a response, decrypting the received message [17,22,23].

To implement human-machine interaction, several additional specialized control interfaces have been developed that allow configuration of connected devices and control of the main parameters of their operation.

Based on the developed control block diagram, as well as the modified and adapted control system, a prototype was developed, which is a compact machine solution for testing and debugging the developed solution (Figure 3).
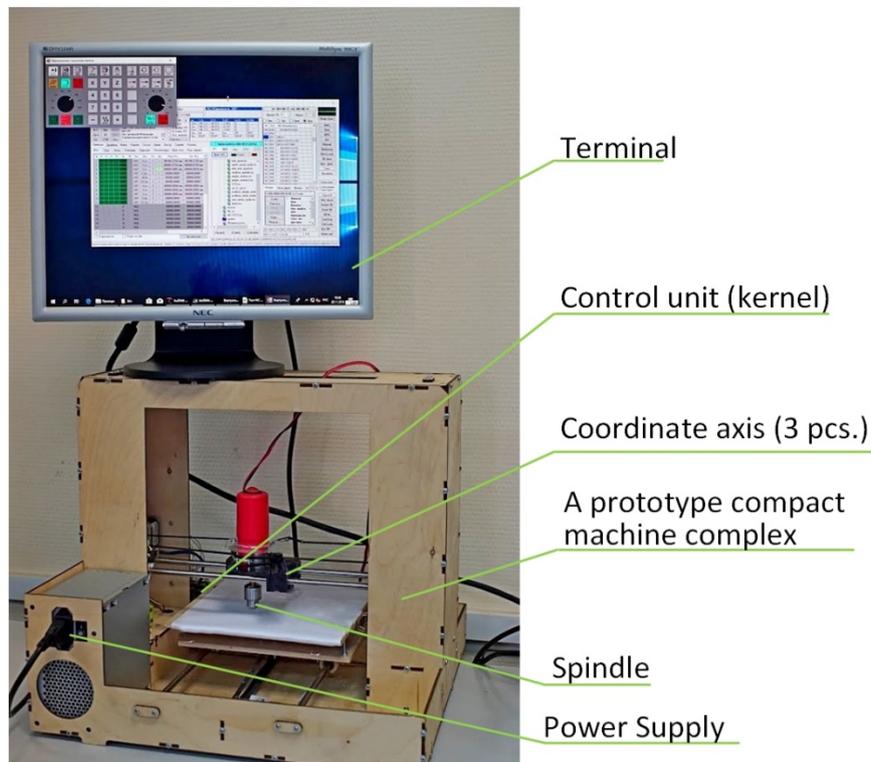
Figure 3. Prototype of a compact machine-tool complex and an adapted system for its control.

The developed prototype of a compact machine that allows for milling processing includes a base case, a control module in the form of a single-board computer Raspberry PI 3, with Linux-based OS, on which the system kernel and the terminal part in the form of a personal computer with the necessary software are functioning. A compiled and improved control system controls three linear axes (X, Y, Z) and the machine spindle according to a given control program in the ISO-7 bit language. The tests carried out showed sufficient accuracy for controlling the axes of the prototype [14,24].

4. Conclusion

The task of constructing a specialized system for implementing numerical control of compact machine solutions is relevant. Similar solutions can be used both in small enterprises and for training specialized specialists in working and programming CNC systems.

The basis for the construction of the control system was used by the domestic cross-platform control platform "AxiOMA Control". To solve the task of controlling external devices via the CAN protocol, as well as their configuration and monitoring, additional modules were developed both in the kernel and in the terminal part of the system. Thus, the synthesis of the basic modules of the "AxiOMA Control" control platform and a set of additionally developed modules made it possible to build a flexible control system that does not have excessive functionality for controlling compact machine tools. At the same time, the general principles of constructing and programming a control system are similar to CNC systems, which allows us to solve the tasks.

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