Construction of a specialized CNC system for thread grinding machines

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The aim of this research is to construct a specialized system of thread grinding machines considering the features of thread grinding and the requirements to increase accuracy, the original structure of the control system for a thread grinder is proposed. This research will present an example of programming a software-implemented programmable logic controller to process the key press of operator's panel.

Keywords— CNC system, thread grinding, Soft PLC, CNC system structure

I. INTRODUCTION

The solution of technological re-equipment tasks for Russian machine-building enterprises involves a widespread adoption of modern thread grinding equipment. The precision of the obtained parts using such equipment determines the quality of the final products (including mechanical products) and depends significantly on the accuracy of the grinding tool (cutting disc). A comprehensive solution to the automated cutting and subsequent grinding any thread profile problems on CNC thread grinders is one of the means of improving the quality of products in many fields like Russian defense, industrial, aircraft, shipbuilding, spaceship's rockets and nuclear complexes [1].

Thread grinding machines are used in the production process of precise threads, as the machine tool grinds the thread of taps, calibers, mills, crimping wheels etc. When grinding, the method of copying the profile of the grinding wheel's working surface is used, according to which the profile of the surface to be formed must coincide with the profile of circle [2].

Editing of single-profile thread grinding wheels is carried out with diamond pencils or needles generally on the machine tool itself. Multiple circles are usually rolled with special metal rollers or are ground with a diamond tool copier outside the machine. are provided [3].

II. CNC SYSTEM "AXIOMA CONTROL" FOR THREAD GRINDING MACHINES

In Moscow At the Moscow's machine-tool factory "Salyut" was created an increased accuracy thread grinding machine with model 80/480. The maximum length of the installed part: 700 mm; the largest diameter of the installed part: 80 mm. Constructive solutions are aimed to implement a set of functions for grinding various threads with increased accuracy. The machine is equipped with a native CNC system " AxiOMA Control".

Controlling the thread grinding machine has a number of technological features [4]. Considering that the accuracy of the thread profile in multi-profile grinding is slightly lower than in the case of single-profile grinding, it is economically expedient to apply the multi-profile as a preliminary operation. The finish grinding is made by a single-profile grinding disc.

The purpose of the development of the machine is to provide Russian production and substitute the importing components products, i.e. to create a native CNC system for a wide range of purposes with an open modular architecture for acquisition a new and modernized machining equipment with computer numerical control [5].

In Fig. 1 is a sketch of the universal thread grinding machine model 80/480.

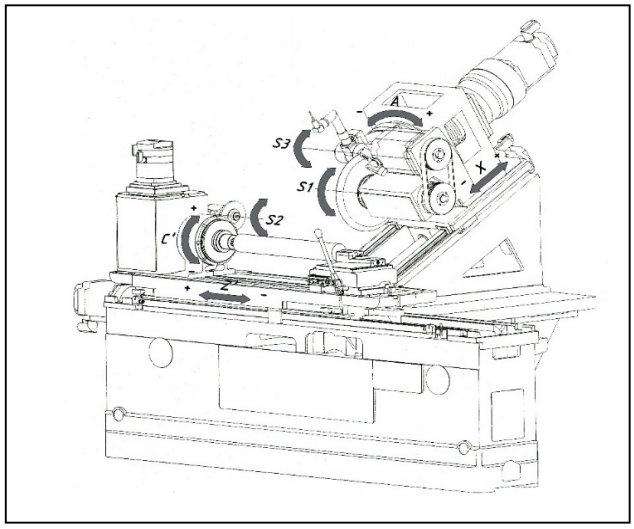

Fig. 1. Universal thread grinding machine model 80/480

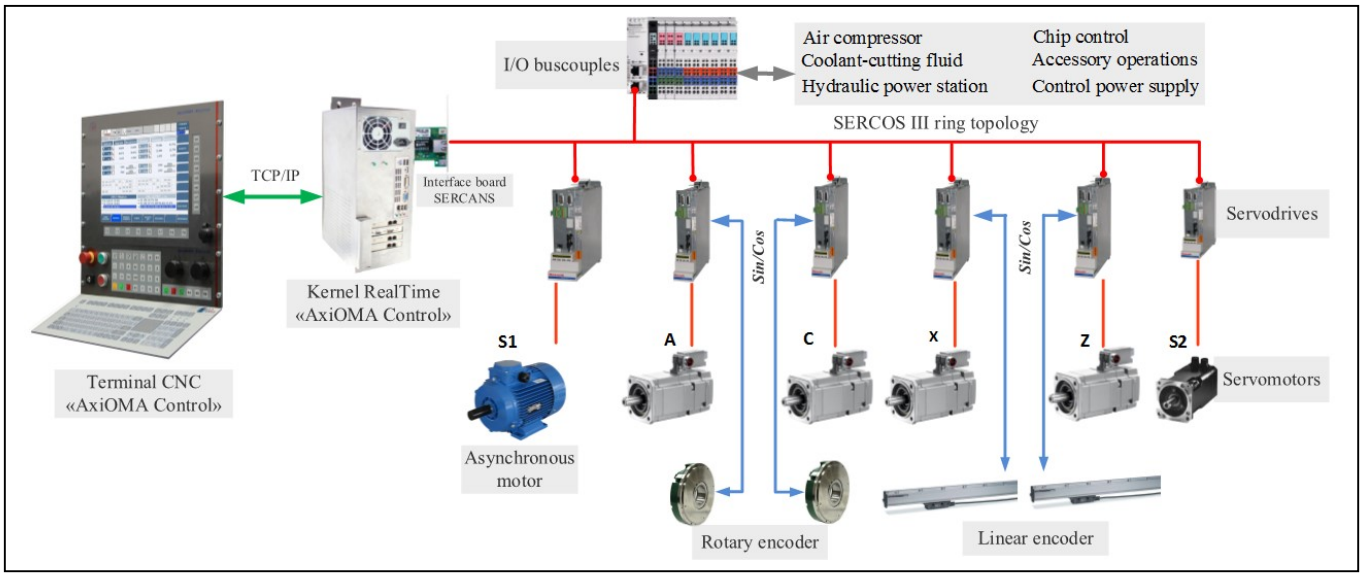

Fig. 2. Structural diagram of connection of devices of universal thread grinding machine model 80/480

The machine has two rotary axes (A, C), two linear axes (X, Z) and two spindles (S1 - main movement, S2 - high-speed roller for straightening an abrasive circular path). The S3 axis is optional (it is used to install a measuring head) and is not used in the basic machine model..

This machine has the following design features: axis A is a retained pneumatic brake; axes A, C and X are connected to the motors through gearboxes, and for axes X and A, static compensation is also required. This should be taken into account when implementing the controlling mechanism. CNC system " AxiOMA Control " implements the kinematic scheme of the machine, compensates the axis play and errors of ball screw pairs, and realize static and dynamic moments.

High-speed SERCOS III interface is used as a fieldbus to control the main feed and movement drives, as well as remote inputs/outputs (Fig. 2) [6].

The PCNC-2 class CNC systems have two-computer architecture i.e. the kernel of the system is installed on a real-time machine (Linux RT OS) and is connected via TCP / IP protocol to a terminal computer [7].

This architecture has its advantages due to the fact that the CNC kernel functions separately from the terminal part, which means that its computing resources are spent only on the necessary tasks of generation of geometry and controlling the machine magnetics [8]. It should also be taken into account that CNC terminals can be configured not only for machine parameters, diagnostics of its parameters, etc., but also more demanding operations such as 3d modeling of processing or the work of a postprocessor to obtain from the CAM model itself the G-code of the control program.

The servodrives of the machine are closed in position using incremental rulers and rotation angle sensors. Rulers and angular sensors are connected to high-speed inputs of drives for processing current positions of the X and Z, A and C axes coordinates. Information exchange is carried out via Sin/Cos signals. Emergency limit switches and reference sensors are connected to the corresponding drive terminals, and also are duplicated to the inputs of passive input/output modules to process these signals using Soft PLC.

III. Features of the Implementation of the Programmable Control Logical Task

In this control system, instead of using usual hardware PLC, a software implementation approach of PLC is used.

Transition the basic programmable logic controller subsystem, from the hardware PLC to the software-implemented controller (Soft PLC) allows, on one hand, to reduce the cost of the control system, on the other, to make quick modernization and reconfiguration of the programmable logic controller subsystem with minimal costs (by transferring all the logical operations and communication components from the PLC level to the core level of the CNC system, as well as using passive modules as input/output devices). Thus, there is no need for additional equipment and it becomes possible to program Soft PLC directly from the CNC system, as well as provide a competent approach to design the control process equipment [9].

Soft PLC in addition to the basic functions of usual PLC such as coolant supply, control hydraulic and pneumatic stations, etc., and processing the tasks of activating the drives, it adds programmable keys for the operator's machine toolbar (Fig. 3).

Additional keys in this implementation of the CNC system are necessary to control various devices of the PLC directly, using the signals from the machine toolbar. Thus, it is possible to conduct testing without running any control programs and use additional functionality that was not originally built into the control system. In Fig. 3 shows an example of implementation such a program in which the button block

processes the input signals from the physical buttons and then transmit it via NC-PLC to the Soft PLC.

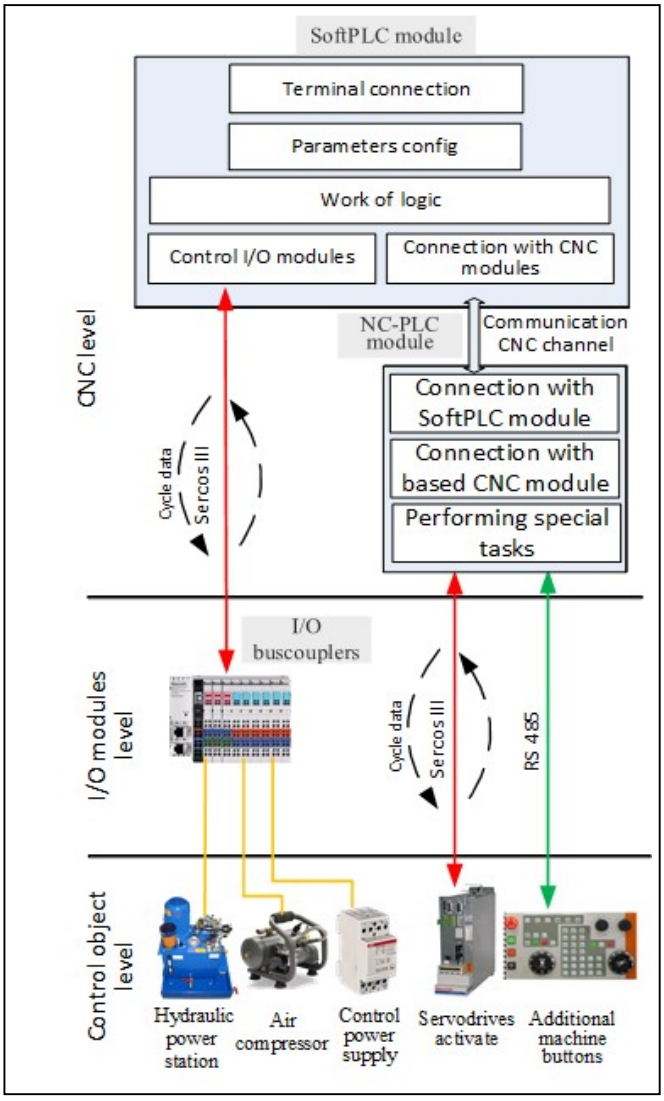

Fig. 3. SoftPLC modules diagram implementations in the "AxiOMA Control" CNC system

At the level of the control system are the module of the software implemented controller and the NC-PLC module.

The SoftPLC module contains the following set of submodules. The communication submodule with the terminal of the CNC system is necessary for transferring diagnostic information, recording and debugging PLC programs, configuring remote I/O.

The parameterization submodule is required for configuring individual I/O devices, plc axes, etc. Also in this submodule there is a verification of devices, a test of their operability, the formation and transmission of appropriate messages to the communication submodule in the terminal.

The submodule of logical work is intended for performing logical and arithmetic operations in accordance with the developed control programs of the machine magnetics. In this submodule, the current signals from the submodule working with the inputs / outputs are processed by the program and written back.

The communication submodule with various modules of the CNC system allows receiving information about the state of the CNC system using a specialized NC-PLC information transfer channel.

The NC-PLC module is a powerful tool for obtaining various information about the operation of the CNC system, as well as communication with various external devices. This module is configurable - it is possible to transmit for the information that is necessary for the current task, which allows to exclude overload of the control channel [10].

Using the connection of the SoftPLC modules and the NC-PLC, a number of simple tasks can be solved: activation of the drives or control of additional keys of the machine panel [11].

IV. PRACTICAL USE OF THE PROPOSED CONSTRUCTION

After all the theoretical studies and test simulations of the work processes of the thread grinding machine being developed, practical tests were conducted on the 80/480 model of machine. The basic elements of the machine are shown in the figure 4.

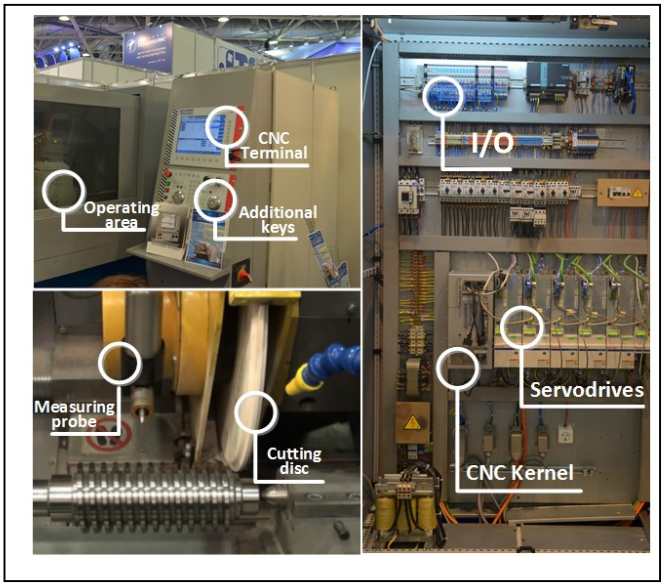

Fig. 4. Basic elements of thread grinding machine model 80/480

In the upper left corner there is a general view of the machine on which the operating area and the terminal of the CNC system "AxiOMA Control". Also shown are additional programmable machine keys that allow you to control various auxiliary equipment (hydraulic station, compressor, etc.)

On the left is the electrical cabinet of the machine, on which the used inputs / outputs of the machine, feed and spindle drives, and also the kernel of the CNC system are allocated. This corresponds to the developed diagram shown in Figure 2.

The operating area of the machine is shown in the lower left corner in more detail. This machine model can not only process the thread by grinding, but also measure the results [12]. This is necessary to continuously monitor the workpiece and achieve high accuracy. Also on this machine there is a special diamond disk for dressing the grinding wheel [13]. All the accuracy data is transferred to the control system, where, if necessary, the trajectory is recalculated and corrections are made for the machining of the part [14]. This design reduces downtime: there is no need to measure the part in a special metrological laboratory, or to correct the circle on another machine. All operations are performed on one threaded grinder.

To start the CNC "AxiOMA Control", a method of synthesizing a mathematical kernel consisting of separate program modules is used, which allows to determine the computing capabilities of the hardware platform [15].

Software mandatory modules are the master module, the self-test module and the communication module with the terminal part of the CNC "AxiOMA Control" system.

The master module is required for communication between other modules: the solution of the generation of geometry, the setting of the control commands from the CNC to the activation of the drives, the moment when it is necessary to open the pneumatic brake, etc., obtaining the current data on the measurement of the part, the activation status of the drives, the operation of the lubrication system guides, etc.

The main software selectable modules are the module for working with the machine magnetics for solving the logical control task, and also the verification module for verification of external devices (working with the measuring probe and activating the drives) and device configuration.

The module of machine magnetics provides performance of such tasks as: control of pneumatic brake of axis A, feeding of lubrication of guides, lifting and lowering of measuring probe, as well as collecting information from it.

TABLE I. INITIAL CHARACTERISTICS OF THE HARDWARE/SOFTWARE PLATFORM

	Without CNC	**Empty modules**	**CNC not work**	**CNC work**
Load CPU, %	5	18	15	41
Load RAM, MB	200	150	410	530
Cycle tact, ms	-	0,05	0,1	0,3

The data verification module is required to verify the configuration of the controlled devices, as well as to process information from the measuring probe, obtained through the module of the machine magnetics.

Initially, the initial load characteristics of the platform on which the CNC system operates are determined.

The Table I shows the initial removed characteristics of the hardware/software platform in several cases. The first case (the first column), when the CNC system is not running on the platform under consideration (only Linux RT with OS applications is running), the second case (the second column) is the work of empty modules in Linux RT without the running NC system, the third case (the third column) is the system CNC is started, but is idle (does not perform any tasks), fourth case (fourth column) - the CNC is started, the part program is running.

After obtaining the initial characteristics, special test programs are used, in which the number of control components is cyclically increased until the computational thresholds (CPU, RAM) of the execution platform are reached.

Based on the resulting values received, other selectable modules can be added to the CNC engine, for example, the remote control and diagnostic module [16]. If, of course, after the loading of all modules and control components, there remains the supply of computing capabilities of the software and hardware platform.

Using such a method it is possible to calculate in advance most of the system load variants at the design stage, thus reducing the probability of occurrence of abnormal situations related to the lack of computational resources and the inability of the hardware/software platform to perform the tasks assigned.

CONCLUSION

Design and technical features of thread grinders placed high demands on the CNC system. Technological and architectural ideas incorporated in the control platforms "AxiOMA Control " made it possible to create a specialized CNC system for thread grinding machines.

Using a programmable controller (for machine magnetics and measuring probe tasks) in the CNC system made it possible to reduce the cost of the control system, while ensuring, at the same time, the possibility of rapid modernization and reconfiguration of the system.

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