Obrabotka metallov (tekhnologiya, oborudovanie, instrumenty) = Metal Working and Material Science. 2024 vol. 26 no. 1 pp. 55–65
ISSN: 1994-6309 (print) / 2541-819X (online)
DOI: 10.17212/1994-6309-2024-26.1-55-65

NSTU NETI

Obrabotka metallov -
Metal Working and Material Science

Journal homepage: http://journals.nstu.ru/obrabotka_metallov

# Adaptation of the CNC system of the machine to the conditions of combined processing

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**ARTICLE INFO**

*Article history*:
Received: 11 December 2023
Revised: 25 December 2023
Accepted: 08 January 2024
Available online: 15 March 2024

*Keywords*:
*CNC* machine
Electrochemical grinding
Programmable device
Automatic control
Combined processing
Control program

*Funding*
This research was funded by Russian Science Foundation project N 23-29-00945, https://rscf.ru/en/project/23-29-00945/

*Acknowledgements*
Researches were conducted at core facility of NSTU "Structure, mechanical and physical properties of materials".

**ABSTRACT**

**Introduction.** Increasing the efficiency of processing technologies for products made from modern high-strength, difficult-to-process materials with increased physical, mechanical and operational properties consists not only in improving the technology itself, the tools for its implementation, but also in modernizing technological equipment taking into account new achievements in the field of mechanical engineering. Modern computer numerical control (*CNC*) equipment is now quite advanced in terms of controlling basic cutting movements. Adaptive monitoring and control systems, as a rule, additionally installed on processing equipment, make it possible to further improve the quality of processing parameters. With the development of new hybrid and combined technologies that combine several types of influence on the product being processed, the issue of synchronizing the automatic control of the movements of parts of technological equipment with the control and management of accompanying processes of combined technologies has become acute. One example of such technologies is electrochemical diamond grinding with periodic dressing of the working surface of a diamond wheel using reverse polarity current. The polarity of the current and the duration of its pulses are controlled by special programmable devices. Current switching units are connected to it. It serves to supply alternating currents of direct and reverse polarity to the electrical circuit and is made on the basis of key elements. Installing such programmable devices on *CNC* machines leads to its' equipping with an additional autonomous automatic control system. At the same time, it is difficult to coordinate the operation of the machine's *CNC* system, which controls the movements of its working parts, and the programmable device used to control the polarity and duration of current pulses during combined processing. **The purpose of the work** is to synchronize the *CNC* system of the machine with the control system for the process of periodically changing the polarity of the current. The study was carried out on an experimental stand. **Methods.** The research methodology involved conducting an experiment consisting of synchronizing the operation of the machine's *CNC* system with the operation of the control system for the process of periodically changing the polarity of the current. To evaluate the results, the time of movement of the diamond wheel as a result of the working stroke was compared with the duration of current pulses of different polarities specified in the control program of the developed software. **Results and discussions.** As a result of the research, it is established that the developed software and hardware complex makes it possible to synchronize in the *CNC* system of the machine tool the control of the movements of the working parts with automatic control of the periodic change of current polarity during electrochemical diamond grinding, which can significantly expand the technical capabilities of *CNC* machines.

**For citation:** Borisov M.A., Lobanov D.V., Zvorygin A.S., Skeeba V.Y. Adaptation of the CNC system of the machine to the conditions of combined processing. *Obrabotka metallov (tekhnologiya, oborudovanie, instrumenty) = Metal Working and Material Science*, 2024, vol. 26, no. 1, pp. 55–65. DOI: 10.17212/1994-6309-2024-26.1-55-65. (In Russian).

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## Introduction

To improve the process efficiency for items made of modern high-strength, tough-to-machine materials with advanced mechanical and physical properties and performance, it is required both to improve the process itself and the process-related tooling [1–7], and to upgrade the equipment taking into account the new technologies in the field of the mechanical engineering. In this case, the prospective efficiency improvement can be achieved by process control automation that could reduce considerably the machining and handling time and improve the finish quality and productivity. As of today, modern *CNC* machines are far enough advanced to control the main cutting movements [8–10]. Adaptive control systems that process equipment is usually fitted with contribute to making the process quality even higher. With advances in new hybrid and mixed technologies [11–20] that combine several types of action on the item to be machined, the issue of timing between the automatic control of process equipment driven elements movement and companion process control of the mixed technologies became critical.

One of examples of such technologies is electrochemical diamond grinding with regular dressing of the diamond grinding wheel face by reverse polarity currents [21–24].

To make electrochemical action on the material to be machined possible, an electrical circuit comprising the *DC* source, the material to be ground and conductive diamond wheel is created. Electrolyte fluid is fed to the grinding area. For machining, the workpiece is connected with the positive contact of the current source. The surface under machining became softer that contributes to the diamond grinding modes improvement. However, during operation, the efficiency of the diamond-bearing layer degrades due to fouling. Tool cutting performance restoration is required, and one embodiment is the current source polarity reversing that makes electrochemical dressing of the diamond-bearing layer possible. Thus, to maintain the wheel performance, periodic current pulses are fed to the electrical circuit. Special programmable devices are used to control current polarity and pulse duration [25]. These devices are connected to current switching units. These key element-based units serve to feed direct and reverse polarity currents alternatively to the electrical circuit. *CNC* machines fitted with such programmable devices require additional non-interacting automatic control system to be used. In this case, it is challenging to coordinate the driven elements movement control system of the *CNC* machine and the programmable device that controls current pulses polarity and duration during the mixed processing.

In this regard, ***the purpose*** is to synchronize the machine's *CNC* system and the current polarity switching control system.

## Methods for studying

To investigate the process of automatic control of current polarity during electrochemical grinding and regular dressing of the diamond grinding wheel face using the machine's *CNC* system, we used a proprietary test bench. The test bench is based on a three-axis *CNC* machine, presented in fig. 1.

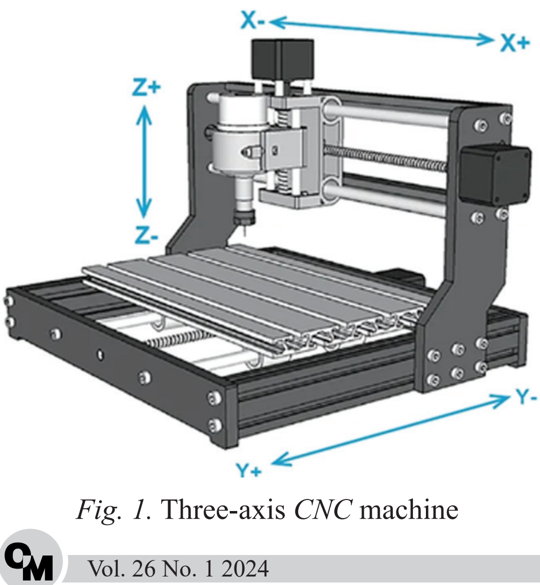


*Fig. 1.* Three-axis *CNC* machine

The machine is equipped with three step motors controlled by the *Arduino* control board and *G* codes. For a process sequence programming, a *PC SW* is used.

Fig. 2 shows *arduino*-based *CNC* machine control logic.

To simulate the mixed processing conditions, the test bench was additionally fitted with *DC* circuit comprising the current source, current switching unit, material to be machined, and grinding tool. The spindle was installed horizontally and fitted with a grinding tool mandrel. The machine components that are the part of the electrical circuit as well as the workpiece holder were insulated by dielectric joints.

Overview of the test bench with retrofits is shown in fig. 3.

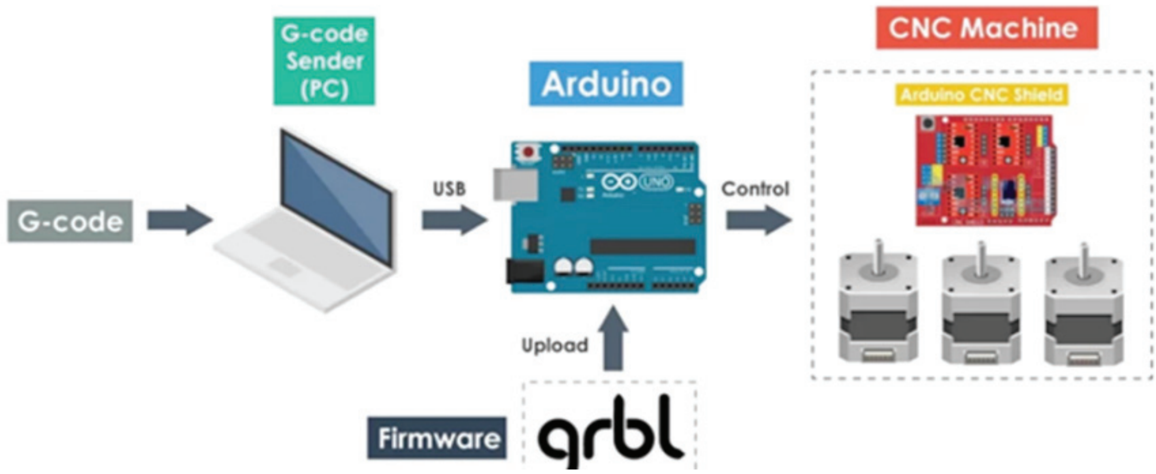


*Fig. 2. CNC* machine control circuit using *Arduino*

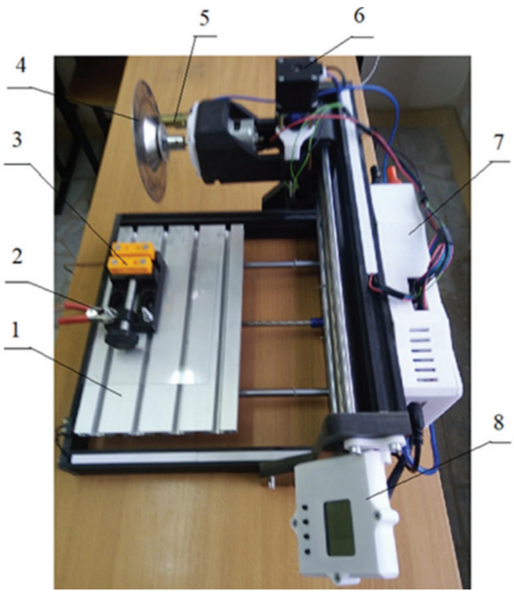


*Fig. 3.* Experimental stand:
*1* – machine table; *2* – connecting terminal; *3* – device for installing the workpiece; *4* – diamond wheel; *5* – brush device; *6* – stepper motor; *7* – integrated control device; *8* – display unit

To control the electrochemical processes during the investigation, the test bench was additionally fitted with the proprietary current polarity control board and relay block, which were coordinated with the existing step motor control board of the machine. Such configured device was housed inside the integrated control unit casing made by additive manufacturing, see in fig. 4.

At the side of the integrated unit, there are "*IN*" and "*OUT*" terminal blocks. The purpose of these blocks is to supply *DC* to the integrated control unit and transmit current pulses of the appropriate polarity to the material to be machined and the grinding wheel.

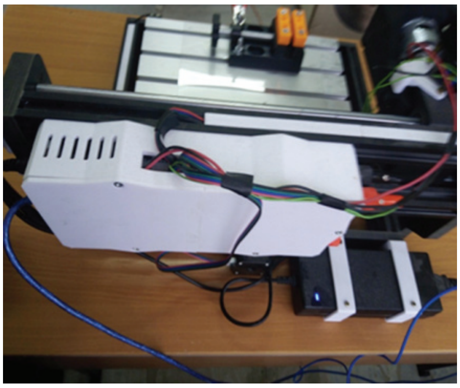

*Fig. 4.* Integrated control device

To start the investigation, first, the step motors were calibrated. For this, proximity switches were used. Using these switches, the initial position of the machine slides in the machine's coordinate system was set for correct execution of the process sequence. The process sequence programmed with the *G* and *M* codes is conveyed from the *PC* memory to the *Arduino* control board via *USB* connection. The process sequence controls the machine drives and current polarity of the circuit comprising the current source, current switching unit, conductive grinding tool and the material to be ground.

One of the investigation targets is to time the machine drives and circuit current polarity reversing. Current polarity may be reversed either in sequence during operation at set time intervals (for electrochemical grinding and dressing) or when changing the material to be machined from one to another (soldered joints, sandwich materials).

According to the investigation procedure, an experiment should be performed, during which the machine's *CNC* system shall be timed with the current polarity switching control system. For the purpose of the results estimation, we compared the time for the diamond wheel movement during the working stroke with the pulse duration of various current polarities set by the process sequence of developed *SW*.

## Results and its discussion

During the investigation, we developed the shared control logic for the machine's step motors and current polarity reversing relay block shown in fig. 5.

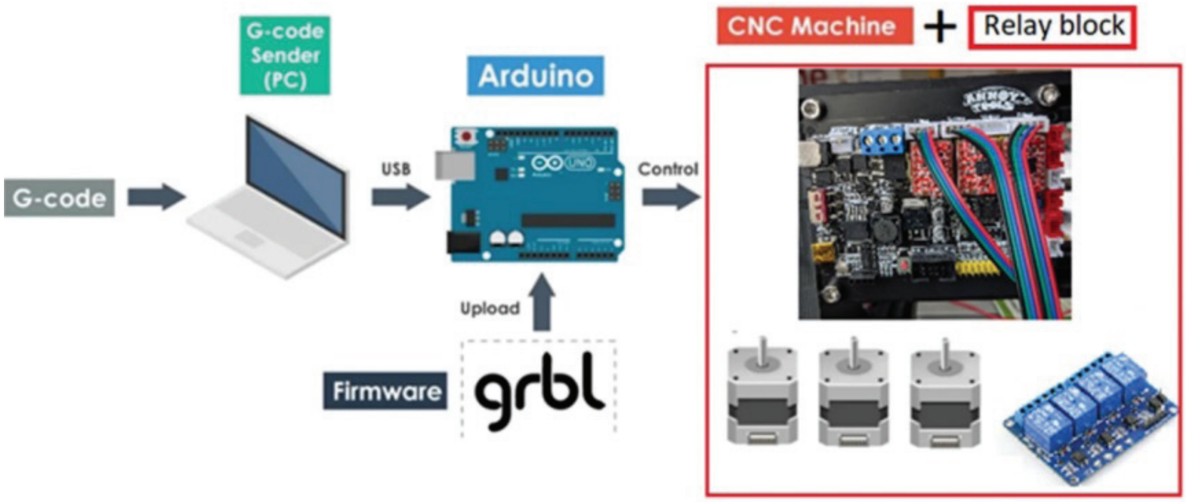


*Fig. 5.* Joint control circuit of machine stepper motors and relay unit

To time the machine's driven element step motors control with the relay block operation, we developed special *SW* for automatic control of step motors and relay block shared operation.

Special software interface is shown in fig. 6.

In the *SW* interface, there are fields to display axis motion coordinates, area for axis movement manual control, window to display the set process sequence and enter the required values as well as virtual bar to select the program codes. Besides, using the interface, one can specify the *PC COM* port to be used, manipulate, safe and open process sequence files, start/stop/terminate program execution, monitor line current polarity and voltage, retrieve error messages, delete files.

Apart from the underlying codes, such as ***G00*** – fast positioning. ***G01*** – linear interpolation. ***M3*** – spindle rotation activation and ***M5*** – spindle rotation deactivation, special codes were developed and introduced. For example, ***M7*** – current polarity reversing activation/deactivation commands, ***M8*** – direct current polarity activation, ***M10*** – reverse current polarity activation, and *M11* – switch to interactive control of current polarity. Duration of the set polarity current pulse is set in an interactive way from the indication unit using the data display panel, shown in fig. 7.

In fig. 8 an analytic model to test the developed process sequence is presented for shared operation of the machine's *CNC* system and the current polarity switching control system when changing the material to be machined from material **1** to material **2**, namely, for the grinding wheel movement along the *Z* axis.

In fig. 9 readings of the indication unit display, used for interactive operation, obtained during the experiment are presented.

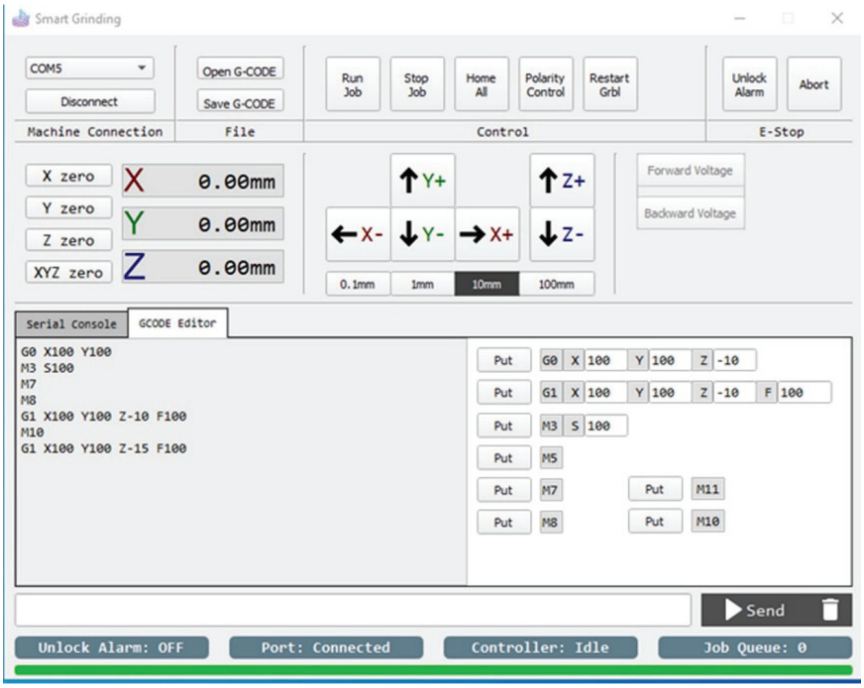


*Fig. 6.* Software Interface

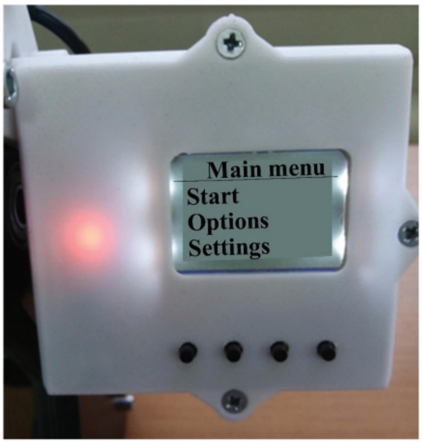


*Fig. 7.* Data display block for interactive operation

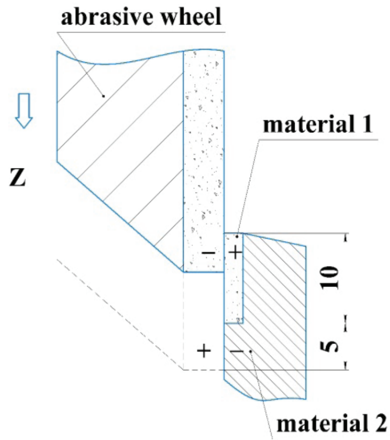


*Fig. 8.* Design circuit for testing the control program


*a* *b*

*Fig. 9.* Display unit display readout:
*a* – display readout for current of direct polarity; *b* – display readout for current of reverse polarity

Current time is displayed in the dark background field, the time reference point is fixed. The reverse or direct polarity current pulse duration is displayed in the light background field. As it can be seen from the readings, set duration of the direct polarity current pulse is 10 s, duration of the reverse polarity current pulse is 5 s. With the grinding wheel movement along the *Z* axis programmed as 10 mm and 5 mm at a speed of 1 mm×s$^{-1}$, time for movement is also equal to 10 s and 5 s. Thus, the machine's *CNC* system and current polarity switching control system were timed.

## Conclusion

The investigation results demonstrate that using the developed hardware and software package, it is possible to time the machine's *CNC* system that controls the driven elements operation and the current polarity switching automatic control system during electrochemical diamond grinding, thus, making a considerable contribution to enhanced performance of *CNC* machines.

It is estimated that the field of future investigation is in fine-tuning of electrochemical diamond grinding process with current polarity alternation, using *CNC* machines and developed hardware and software package for automatic control as well as the package upgrade for other types of mixed processing.

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## Conflicts of Interest

The authors declare no conflict of interest.