Remote Machine Tool Control and Diagnostic Based on Web Technologies

G. M. Martinov[1], A. B. Ljubinov[1], L. I. Martinova[2], A. S. Grigoriev[1]

[1] Department of Computer Architecture Control Systems, Moscow State Technological University “STANKIN”, Russian Federation

[2] Department of Manufacturing Engineering, Moscow State Technological University “STANKIN”, Russian Federation

Abstract

In order to ensure the competitiveness of production one has to reduce the machine idle time caused by tool failure and to carry out scheduled preventive maintenance work. To solve these problems, standalone or integrated in the CNC system measurement tools are used in order to configure the servo drive and to diagnose inputs/outputs of the PLC. The use of modern web-technologies for creation of system management software allows end users to arrange remote control of machine tools, along with remote monitoring and adjusting from the diagnostic centre of machine tool builders. It is important to diagnose the geometric and logical control tasks. An approach to creating a diagnostic tool based on virtual instruments that can be integrated in a web-browser is proposed.

Remote NC terminal duplicates, replaces or supplements the main terminal of the control system. The specific is that remote terminal can use a different platform and its visualization screen is more laconic. The access to basic functions of the NC kernel should be performed through a local or corporate network, as well as via the Internet. The principles of developing remote terminals as new components of control systems with web-based technologies are considered.

Keywords

Remote control, Remote diagnostic, CNC, Digital oscilloscope

1 INTRODUCTION

Modern CNC machine tools are complex mechatronic systems, which are maintained by highly qualified specialists in well-equipped service centres by means of remote control [1]. This raises a strong need for diagnostic software for remote analysis of input and output signals of the executive machine modules [2].

The remote diagnostic system should be able to measure and read the signals, store the results of measurements together with the measurement configuration, perform computing operations on the measured signals, to publish the measurement reports in the form of an oscillogram. Integrating the feature of remote diagnostics in the CNC system requires special architectural solutions in the control system [3].

The process of geometric movement, called geometric task, and the process of controlling miscellaneous equipment, called logical task of CNC are critical to the machine tool. Those processes should be diagnosed first. In terms of geometric task the servo drives involved in the interpolation are diagnosed. In terms of logical task I/O signals of PLC are diagnosed [4].

2 CLIENT-SERVER ORGANIZATION OF CNC SYSTEM

The Hi-end CNC systems of world's leading manufacturers Fanuc, Siemens, Heidenhain Bosch Rexroth, Mitsubishi, Fagor, etc. have two-computer architecture. The kernel of the control system operates on a real-time computer, the HMI (human machine interface) is running on a terminal computer.

The CNC system “AxiOMA Ctrl” has a similar architecture with separate kernel and terminal, connected via Ethernet (TCP/IP) [5]. The communication is implemented according to the client-server architecture using the synchronous and asynchronous data channels (Figure 1).

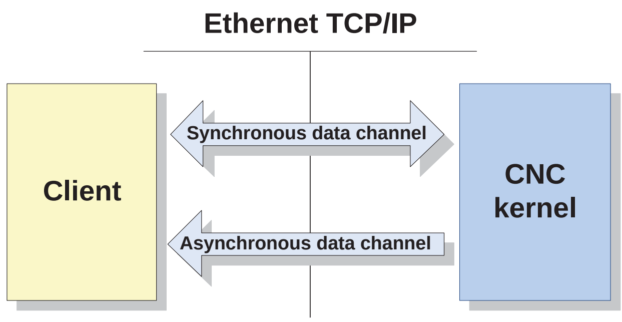

Figure 1 - Data channels in the CNC system

The synchronous data channel is the main one, it provides obtaining data from the kernel, passing data to the kernel and sending commands to the kernel. The asynchronous data channel is used to inform the clients about the changes in the kernel. The protocol of communication between the kernel and the terminal is open, which allows machine builders and third party providers to manufacture their own clients (operator panels, remote control panels, devices of automated data collection and analysis, remote terminals, and so on).

3 SCHEMAS OF INTERACTION BETWEEN CLIENTS AND THE CNC SYSTEM

The interaction between clients and the CNC system is implemented according to one of the following schemas:

- One-to-one relationship (Figure 2 (a)) - each client is connected to one server. The scheme corresponds to the typical machine mode of usage, when the standard operator panel is used as a terminal.
- One-to-many relationship (Figure 2 (b)) - one client is connected to multiple servers. The scheme is used during adjusting, service maintenance or launching a set of identical machines. The operator controls each machine in the group.
- Many-to-one relationship (Figure 2 (c)) - multiple clients are connected to one server. The scheme is used while working on complicated and large machines, where additional panels, detachable consoles, diagnosing tools and specialized adjustment tools are used.

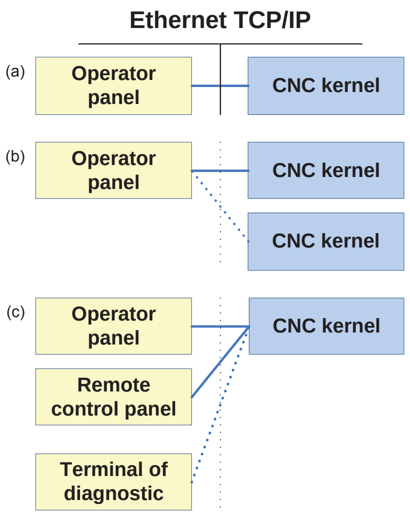

Figure 2 - Schemas of client -server interaction in the CNC system in the local net

Similar schemas of interaction can be applied to Internet as well. That implies using either a standalone Web-server, or a Web-server, integrated in the kernel of the CNC system. The combination of the two variants is possible as well (Figure 3). The functionality of standalone Web-servers can be supplemented with additional data processing, mathematical analysis, statistical functions, etc. But they are slower than integrated Web-servers. The simultaneous client connections to both kinds of Web-servers (Fig. 2 b) are allowed.

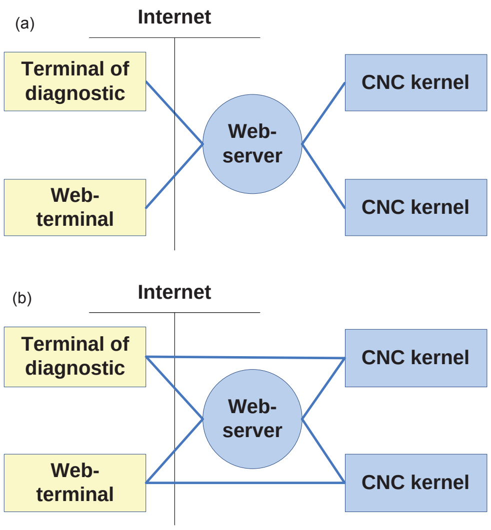

Figure 3 - Schemas of server-client interaction in the CNC system in the global net

4 REMOTE TERMINAL

The organization of distributed control of components is carried out by incorporating them into a common information-computing environment through industrial networks. Large multi-axis machine tools are often equipped with several terminals, including portable operator console [6]. The importance of controlling, monitoring and diagnosing machine tools via remote terminal is increasing constantly. A web-server was developed and integrated into the CNC system (Figure 4). It allows remote clients to work on personal computers, tablet PCs, smart-phones and other terminals to display the operator screen and control the CNC system via the web-browser.

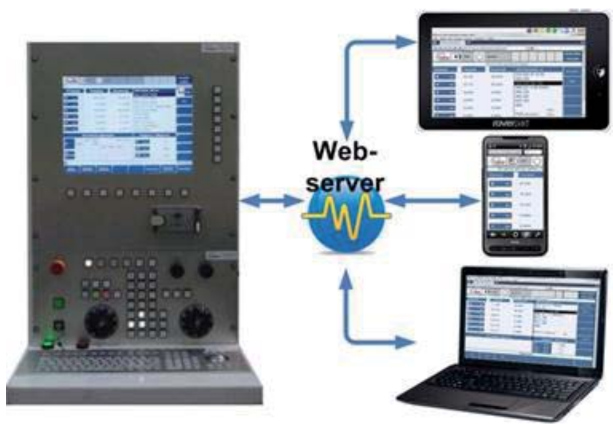

Figure 4 - Prototype of CNC system with built-in web-server

The GUI of remote web-terminal was developed with the help of web-based technologies and implements the basic functionality of CNC system like the main terminal. The web-server provides a single receiving web-page through a browser, so there are no regular updates of the page. The dynamic displaying of changing data capture during the operation of the machine tool is implemented on the base of AJAX (Asynchronous JavaScript and XML) technology, which allows asynchronous modifying of the data on the user's web-page without reloading the whole page. The disadvantage of this technology is that not all mobile platforms support it (for example, the standard browser of Windows CE does not) due to restricted functionalities.

5 COMPONENT ARCHITECTURE OF DIGITAL OSCILLOSCOPE

The digital oscilloscope is one of the most universal configuration tools of process equipment and executive devices.

Leading CNC manufacturers like Fanuc, Siemens, Bosch Rexroth, Mitsubishi, Fagor and others offer an integrated solution of the oscilloscope in their control systems. Other manufacturers, such as Renishaw, and Heidenhain, offer external measuring systems "Ballbar" and "KGM", respectively.

Using the modular approach for digital oscilloscope allows building remote access diagnostic applications on the basis of the common software core.

External measurement systems allow a comprehensive diagnosis of the machine [7, 8], including all elements and feedback, but do not allow carrying out a measurement during processing. On the other hand, a modern CNC system has all required measurement information, or if necessary it can be obtained. Control systems use different diagnostic and configuration applications, although most of them could be implemented on the basis of a certain common solutions.

The core of the digital oscilloscope implements openness to the list of supported measurement devices (Figure 5). Each physical device is mapped to the virtual device with a fixed interface. The work with SERCOS electrical and hydraulic drives, EtherCAT and CAN drives is implemented at this time. The PLC and CNC systems with multiple drives are also supported. In this case master (trigger) device should be selected for starting and finishing the measurement.

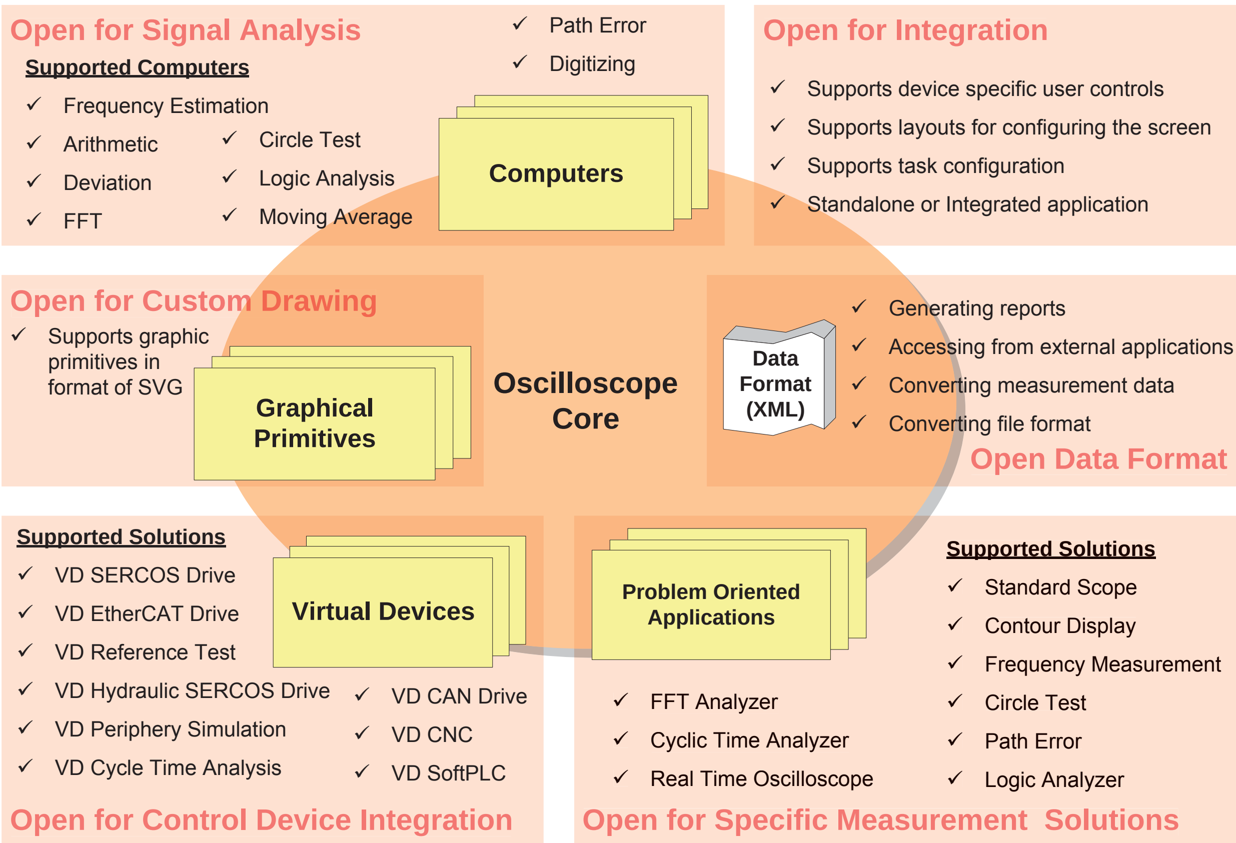

Figure 5 - Concept of digital oscilloscope core

The core provides the hierarchy of objects (devices, measurement signals, triggers, ...), carries out the transformation of coordinate systems, shifting and scaling of signals, formation of logarithmic and Cartesian coordinate systems, etc.

The measured device signals are subjects to mathematical processing. The openness for signal analysis allows the specialist to integrate their own calculators. The basic set implements arithmetic operations, deviation, fast Fourier transformation, frequency estimation, logic analysis, moving average, path error estimation, circle test error estimation according to the standard ISO 230-4, etc.

Visualization components allow configuring measurement and displaying the measured results.

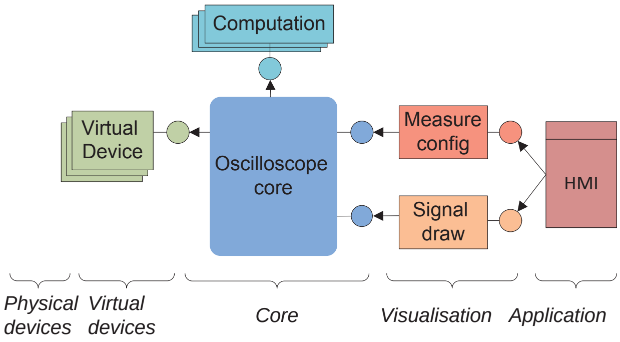

Figure 6 - Component architecture of oscilloscope

Openness for specific measurement solutions (Figure 6) means that different diagnostic applications are built on the base of the core component set like a Real-Time Oscilloscope for online signal measuring, a FFT Analyzer for analysis and determination of resonant frequencies, a Cyclic Time Analyzer to track resource use in case of complex processing, a Contour Display for the trajectory analysis, Frequency Measurement for the analysis of amplitude-frequency characteristics and building body diagrams, a Circle Test for determining the deviation from the circle according to the standard ISO 230-4, a Logic Analyzer to analyze the PLC signals [9, 10]. The examples of applications, built on the base of digital oscilloscope components set is illustrated on the Figure 7.

An application which displays the results of measurements often requires special graphic symbols and labels on the screen. The mechanism of openness for custom drawing allows using the SVG (Scalable Vector Graphics) language for describing and visualizing graphical primitives. Using XML format for signal description allows to apply the XSLT (eXtensible Stylesheet Language Transformations) transformation to generate reports, convert formats and process data.

The diagram of circle test (Figure 8) illustrates the use of SVG primitives. The user inputs the information about the circle radius, the direction of rotation (clock wise, control clock wise), the feedrate value; when the measurements have been carried out, a special algorithm scales the error to display it on the screen (error size is several microns). The information about the measurement, supplemented by the coordinate axes is displayed in grey color with the help of SVG.

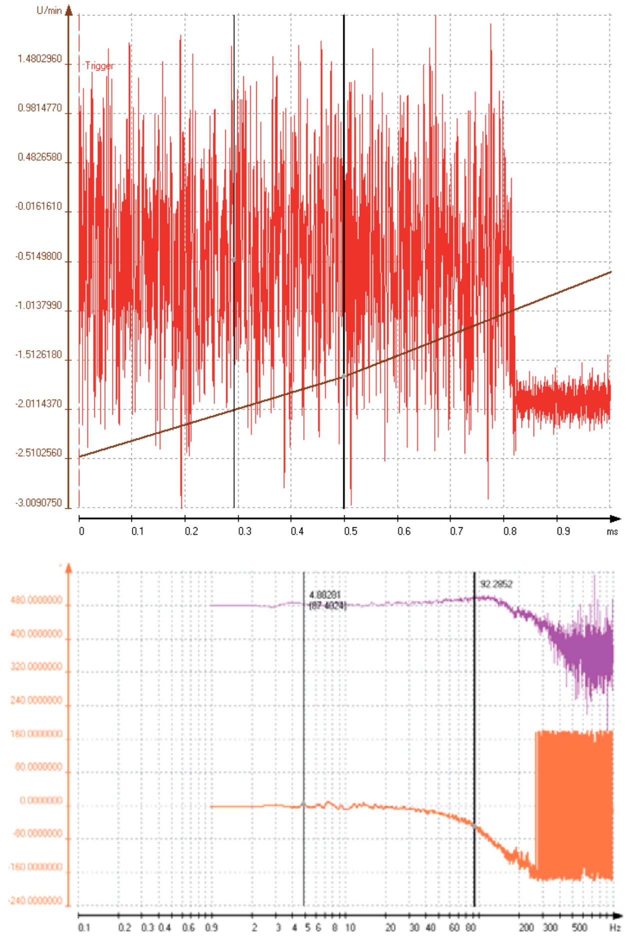

Figure 7 - Moving Average and FFT/Bandwidth signal visualization

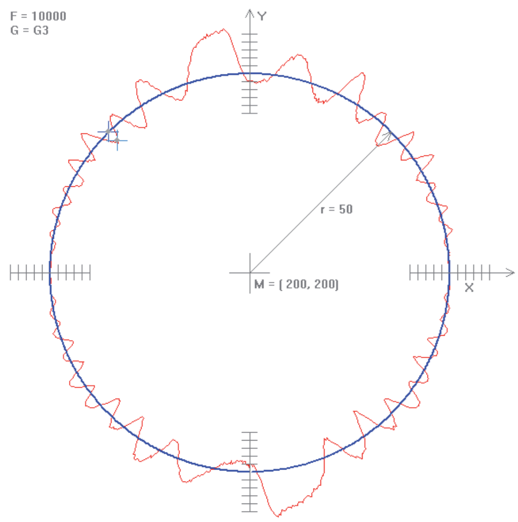

Figure 8 - Circle test application based on a digital oscilloscope core

The component-based approach ensures openness of integration. It is possible to create diagnostic applications built in the CNC system or standalone solutions on the base of a digital oscilloscope.

6 PRACTICAL ASPECTS OF USING WEB-TECHNOLOGIES

A lot of reasons, such as existing ready-mades on the market, easiness of use, apparatus and program platform independence, easiness of integration into user applications and the ability to describe almost any type of complicated data, have contributed to the mass spreading of XML. The information in the form of XML can be processed not only by machines, but by people as well. The widespread using of XML raised the idea to use it for storing diagnostic data. XML format is used for storing information on measurements configuration (measure points, used channels, conditions of start and end trigger, sampling time, …), the values of measured signals and information on the computations applied to them, settings of display and so on. The values of measured signals are stored as binary code in an XML tag, because the number of measured points in a signal can exceed 500 000, and processing of those signals could take an inadmissibly long period of time.

The measurement data stored in the XML format is processed by XSLT scripts for converting data formats, reports generation, information filtration, and so on (Figure 9). The end user writes his XSLT scripts for his purposes and applies them. To do that one has to possess XML data format description or *.xsd scheme file.

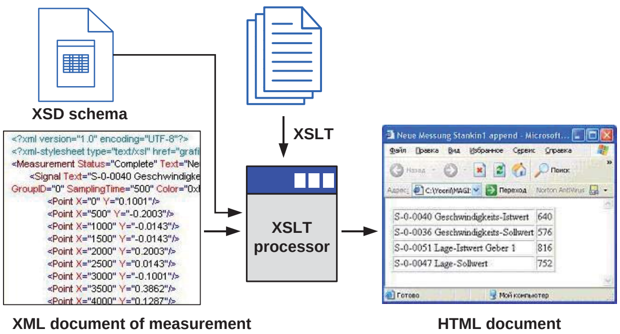

Figure 9 - Generating an HTML report with the help of XSLT transformation

In order to ensure setting-up of machines in the workshop, where the communication with the diagnostic center is limited, SVG signals viewer has been created (Figure 10). It is based on a web-browser, free distributable SVG plug-in, XSLT transformation and JavaScript. This solution, although slower than a typical diagnostic application, allows to view and analyze the measured signals on every PC with a web-browser, with no additional hardware or software restrictions.

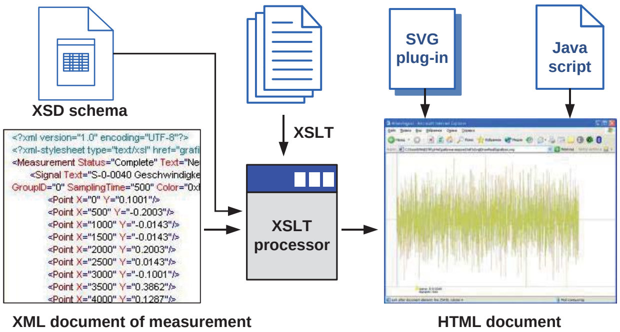

Figure 10 - Visualization of XML data using SVG

7 CONCLUSION

The combination of client-server architecture of CNC system, mathematical processing and signal analysis functions and modern web-technologies makes it possible to create instruments of remote control, diagnostics and adjusting of the machine tools with CNC system [11, 12].

The digital oscilloscope base set of components for control system allows to build on its base both powerful universal diagnostic instruments and easy-to-use diagnostic applications, closely oriented to solve particular tasks.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Sergej N. Grigoriev, Georgi M. Martinov, Scalable Open Cross-Platform Kernel of PCNC System for Multi-Axis Machine Tool, Procedia CIRP, Volume 1, 2012, Pages 238-243.

[2] Sergey N. Grigoriev, Michael P. Kozochkin, Fan S. Sabirov, Andrey A. Kutin, Diagnostic Systems as Basis for Technological Improvement, Procedia CIRP, Volume 1, 2012, Pages 599-604.

[3] Martinova L. I.; Grigoryev A. S.; Sokolov S. V. Diagnostics and forecasting of cutting tool wear at CNC machines // Automation and Remote Control. 2012. Vol. 73. No. 4. P. 742-749.

[4] Sekar, R., Hsieh, S-J. and Wu, Z. (2011) “Remote Diagnosis Design for a PLC-based Automated System”, Int. Journal Manufacturing Technology, Vol. 57, pp. 683-700.

[5] Georgi M. Martinov, Aleksandr B. Ljubimov, Anton S. Grigoriev, Lilija I. Martinova, Multifunction Numerical Control Solution for Hybrid Mechanic and Laser Machine Tool, Procedia CIRP, Volume 1, 2012, Pages 260-264.

[6] W. Lihui, O. Peter, C. Andrew, L. Sherman Remote real-time CNC machining for web-based manufacturing. Robot Cim-IntManuf, 20 (2004), pp. 563–571.

[7] Grigoriev S.N., Teleshevskii V.I. Measurement problems in technological shaping processes // Measurement techniques. 2011. Vol. 54(7). P. 744-749.

[8] Sabirov F. S.; Savinov S. Yu. Diagnostics and Control of The Accuracy of Axis Drives for Automatically Controlled Multicoordinate Metal Cutting Machines // Measurement Techniques 2011. Vol. 54. No. 8. P. 879-882.

[9] G.H.J. Florussen, H.A.M. Spaan, Dynamic R-Test for Rotary Tables on 5-Axes Machine Tools, Procedia CIRP, Volume 1, 2012, Pages 536-539.

[10] M. Mori, M. Fujishima, M. Komatsu, Bingyan Zhao, Yadong Liu, Development of remote monitoring and maintenance system for machine tools, CIRP Annals - Manufacturing Technology, Volume 57, Issue 1, 2008, Pages 433-436, ISSN 0007-8506.

[11] G. M. Martinov, L. I. Martinova Trends in the numerical control of machine-tool systems, Russian Engineering Research, 2010, Volume 30, Number 10, Pages 1041-1045.

[12] Jinia Datta (Das), Sumana Chowdhuri, Jitendranath Bera, Gautam Sarkar, Remote monitoring of different electrical parameters of multi-machine system using PC, Measurement, Volume 45, Issue 1, January 2012, Pages 118-125, ISSN 0263-2241.

10 BIOGRAPHY

Georgi M. Martinov hold degree of Doctor of Technical Sciences. He is currently head of the Computer Architecture Control Systems Department at Moscow State Technological University "STANKIN". His areas of research interest are development of numerical control systems as well as automation of technological processes.

Aleksandr B. Ljubimov is a senior programmer of Computer Architecture Control Systems Department at Moscow State Technological University "STANKIN". His area of research interest is development of numerical control systems.

Lilija I. Martinova hold degree of Ph.D. He is currently docent of the Manufacturing Engineering Department at Moscow State Technological University "STANKIN". Shies areas of research interest are CNC machine tool applications and technologies.

Grigoryev Anton holds MSc.Eng degree in Automatization and Control from the MSTU "STANKIN", Moscow. At the moment he is doctoral student in the micro manufacturing group of ETH Zurich. Current specific area of research is control of waterjet processing, especially surface processing with pure waterjet technology.