Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 1 (2012) 277 – 281

www.elsevier.com/locate/procedia

5th CIRP Conference on High Performance Cutting 2012

Multifunction numerical control solution for hybrid mechanic and laser machine tool

Georgi M. Martinov[a], Aleksandr B. Ljubimov[a], Anton S. Grigoriev[a], Lilija I. Martinova[b]*

"a Department of Computer-architecture Control System, Moscow State Technological" University STANKIN, Vadkovsky per. 1, Moscow 127994, Russia

[b] *Department of Production Engineering, Moscow State Technological University "STANKIN", Vadkovsky per. 1, Moscow 127994, Russia*

* Corresponding author. Tel.: +7-499-972-9440 ; fax: .E-mail address: martinov@ncsystems.ru .

Abstract

Hybrid and also multitasking machine tools are equipped with a multifunction NC system. The popularity of multitasking machines is growing because of the decrease of the necessity to use manufacturing equipment and the reduction of the workpiece refixturing during processing. Hybrid machines provide a more efficient and productive manner of processing with the help of simultaneous and controlled interaction processes by the mechanisms and (or) energy sources. Equipment, which combines machining of parts and laser hardening of their surfaces, is becoming increasingly popular among machine builders as well as it replaces effectively a number of finishing operations to ensure the quality of surface. But the implementation of the hybrid solution is restricted not only from the HMI part, but mostly from the architecture of the control system. The control system laser treatment has its own specifics, so it should be integrated into the overall structure of machine tool as a standalone module. A solution for mechanical cutting and laser treatment on the basis of external interpolation module is implemented in such a way that according to the target solution can be performed simultaneously or separately. On completion of machining the part program switches on a laser for laser hardening. The control system turns off the built-in interpolator and forwards the data to the external interpolation module, the switching procedure is completely transparent to the operator. The paper illustrates the concept and design aspects of the CNC system architecture.

Keywords: CNC for hybrid machine tool; laser structured surface; external interpolation module

1. Introduction

The rapid development of numerical control systems significantly expands the technological capabilities of the industrial equipment, contributing to the efficiency and ensuring the quality of manufactured products.

So at present the trend of multitasking machines is gaining more and more popularity, allowing using the same machine tool to implement various types of machining: turning, milling and grinding [1, 2]. This kind of equipment sufficiently reduces the production cycle, in particular by simplifying routing technology, a significant reduction in set-up time during operations, thereby improving the precision of products by reducing the re-installation work pieces and implementation of the principle of constancy of the bases [3].

In addition, multitasking equipment allows optimizing industrial structure of the company without losing the technological capabilities by+ reducing the range of equipment and production areas [4].

Other perspective directions is hybrid machines, which provide more efficient and productive manner of processing with the help of simultaneous and controlled interaction processes by the mechanisms and (or) energy sources [5]. Laser assisted machining, as a kind of hybrid process, was developed in an effort to reduce the manufacturing costs and is associated with machining of ceramic [6]. In laser assisted machining the laser is used for changing the structure of material in the cutting area [7].

Hybrid and also multitasking machine tools are equipped with a multifunction NC system. There is no

2212-8271 © 2012 The Authors. Published by Elsevier B.V. Selection and/or peer-review under responsibility of Professor Konrad Wegener
http://dx.doi.org/10.1016/j.procir.2012.04.047

big difference in the numerical control systems to control the mechanic and laser machining for multitasking solution with separate handling or for hybrid solution with simultaneous handling. This paper illustrates a NC system architecture, which controls a milling process on the one hand and autonomous laser scanning head on the other hand. The machine tool equipped with such CNC can be used for laser assisted milling or for separate milling and laser hardening.

At the same time new technologies ensuring the quality characteristics of products are becoming more and more popular in industrial production. So, laser hardening of metals, as a type of hard-facing surfaces of pieces that have passed machining becomes widespread. This method ensures high-end roughness of pieces [8] and provides a high surface hardness and wear resistance of parts, that is very important for such products, as turbine blades, dies and molds, engine shafts, etc. Typically used local processing (in the form of laser hardening and laser cladding) of the surfaces of the parts that must meet special requirements for wear resistance, fatigue resistance of the product, particularly under cyclic loading, etc. The need for equipment that implements the laser technology is currently high, and the range of equipment features requested by users, is constantly expanding [9]. For example, it is popular to combine on a single machine tool mechanical and laser processing, which significantly reduces the manufacturing cycle of products by reducing the number of process operation and the amount of reinstalling the workpiece. At the same time mechanical and laser processing performed by a single part program on the same machine tool in a single operation that allows to use the same workpiece refixturing and coordinate systems.

Controling laser processing is a specific task, which has fundamental differences from the control machining [10]. So, while the laser process is performing the control of the beam deflection and the laser spot movement are required, also the control of feed for linear movements is performing. Servo drive control in this case is the same as for usual machining, but the control of the beam deflection and the laser spot movement are quite different tasks for control system. In this regard, laser surface hardening of parts is carried out as a separate control task. However, modern computer systems allow you to carry out this process in a single manufacturing operation, but it takes a special approach to build control systems for hybrid or multitasking machine tool that implements the mechanical and laser processing.

2. Organisation of multifunction control system

Multifunction CNC system for mechanical and laser equipment is built on an open modular architecture that includes several application parts, called management tasks [11]. One of them is geometric task, it responds for the generation of the geometric movement. In our case the geometric task controls the machining and the laser systems. Usually, for the machining processing the geometric task is realized in the NC-kernel, but for laser the solution is divided in two parts: first one in the kernel and second one in the terminal (Fig. 1). A reason for such a decision was the restriction of integration coming from the side of laser scanning head. Manufacturers of deflectors equipped them with PCI or PCIe board and software drivers (as a rule for MS Windows) not in the source code. The integration of deflector control in the CNC system required a new architecture with a mechanism we called external interpolator.

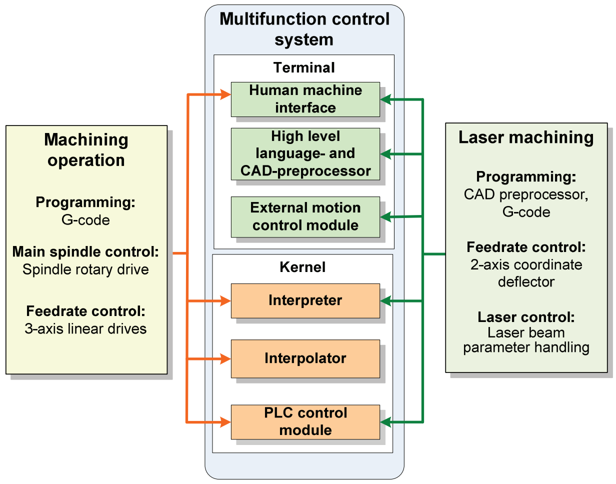

Fig. 1. Organization of multifunction control system for mechanical and laser equipment

The geometric task is implemented by three main modules: the interpreter of part programs, the interpolator, the control module of servo drives. Despite the fact that the interpolator has a modular architecture, its configuration or extension for specific tasks is rather difficult, because it is available only for the manufacturer of control systems. In rare cases, this right may be granted to machine builders, but not completely [12, 13]. In this article a special approach of building a CNC system with an opportunity to add motion control methods for laser processing without modifying the system architecture is proposed [14].

The work area of laser scanning head is restricted to 300 x 300 mm. To cover completely the work piece it is necessary to have a servo drive movement (as a minimum for area positioning the laser scanning head) and movement inside laser scanning head (rotation of mirrors). Performing laser machining requires two types of CNC movements. The first type of movements is implemented by servo drives and controlled directly from the CNC interpolator. Movements of the second type are movements of the laser beam directly in the treatment area, and they are implemented with the system of deflection of the laser beam. The proposed approach involves organizing the control of deflector from a special device - an external module control that has the same interface as the CNC kernel interpolator, but delegates the direct traffic control to an external device (for example, to the controller of deflector) [15]. It is a software-hardware device, which performs the laser processing part of the flow program. According to the target linear movements and laser scanner head movements can be performed separately or simultaneously. In the second case the synchronisation is done on the level of microinstructions, The microinstructions are generated by the external interpolator, which has to define the execution time of each trajectory segment (see below microinstructions of motion control).

A version of the multifunctional control systems for mechanical and laser equipment is shown in Figure 2.

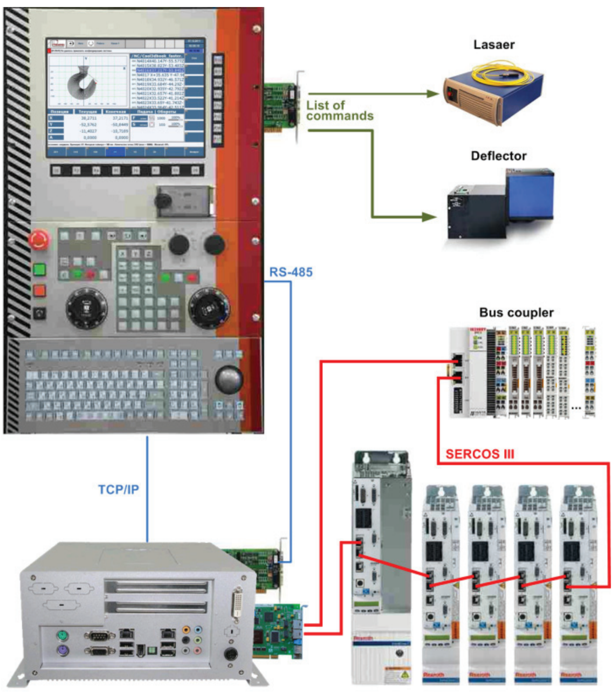

Fig. 2. Structure of the data processing pipeline

The structure of the control system for mechanical and laser equipment includes:

- the operator panel (it also contains an external control module, PCI-board control for the laser and the deflector).
- an industrial computer working in real time. This computer controls the servo drives and PLC.

3. Structure of CNC system with external interpolator

Interaction of the main CNC modules is illustrated in Fig. 3.

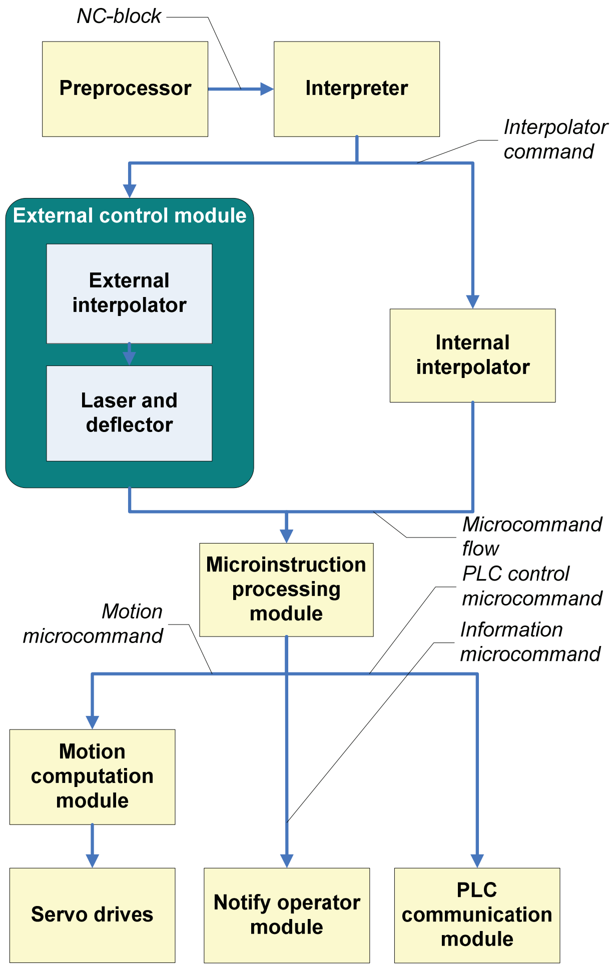

Fig. 3. Block diagram of the control system module with an external control

The CNC system with an external control module includes the following key modules and devices.

The *preprocessor* is used for the pretreatment of part programs written in high level language. The main task of the preprocessor is translation of the high-language part program to G-code. The result of his work is the text in the G-code, with reference to the original part program file and the position of the file. Then this binding allows to display on the HMI the executable NC block.

The *interpreter* translates the text of the part program in command of the interpolator. Examples of typical commands of interpolator are the command of linear motion, when the maximum feedrate and the end point are specified; the command of tool change; commands for cycle logic, etc. Among others, there are commands of switching on external control mode and vice versa.

The *interpolator* (internal or external) converts the commands into the microinstruction of three basic types:

- The information microinstructions serve to inform the machine operator about the current state of processing, they do not run the interpolator or the PLC. Example information microinstructions: microinstruction changes the current file position of the executing part program, microinstruction changes the current GMT-vector (it means list of active preparation and miscellaneous commands also the selected cutting tool and its working edge), microinstruction change the stack of executing subprograms, etc. The information microinstructions do not require real-time processing, it is possible to have a delay of their processing.
- Microinstructions of logic control activate the PLC, run in real time and may require the interpolator to wait till the end of their execution implementation. Examples of microinstructions of logic control: microinstruction turn-on spindle up to a predetermined speed value, microinstruction engaging cooling systems, microinstruction tool change and other microinstructions corresponding to the M-code for executing the machine functions.
- Microinstructions of motion control define the exact trajectory of servo drives that are involved in the interpolation. The microinstructions of motion control include the estimated execution time of each segment of the trajectory and can be buffered.

Mainly *microinstruction processing* module buffers the incoming microinstructions and sorts them by appointment. Buffering avoids the need for generation and transferring of microinstructions in real time.

The notify *operator module* accumulates information and periodically sends to the operator terminal appropriate notifications (about changing the current file of the part program, about change the end position for the executable NC block, etc.).

Module of *motion computation* performs the final calculation of the command of the servo drives parameters defined in real time.

The *PLC communication* module provides the interface to one or more PLC. The PLC is implemented as an integrated or stand-alone operating device, which is hardcoded to a certain set of commands and data requests.

The *external control* module fulfils the commands of laser processing independently, when control is passed to it. If necessary, the external control module can control servo drives and PLC. In operation, the external control module provides the module of processing microinstructions with current information to display on the screen. In particular the current coordinates, the number of current executable block and other parameters are transmitted.

Commands created by the interpreter in the processing of the part program are available for the interpolator, as well as for the external control module. Thus, the possibility of direct servo drive control and deflector management from one part program is implemented. According to the target the implemented solution could be used ether for multitasking or for hybrid process. Execution of the part program is as follows:

- if the command to switch to external mode control appeared in the part programme, the built-in interpolator is switched into the wait state, and external control module receives a command for executing;
- the external control module sequentially processes commands of interpolation and the controller interface functions are invoked according to the command.
- during command execution the module of external control receives the current parameters values from the object and passes them to the laser controller as microinstructions, also the current position and the other information are updated in the terminal part;
- the external interpolator is switched to the wait state when the command "switch off the mode of external control" appears in the list.

Such an organization makes the CNC system architecture universal and allows combining mechanical and laser processing on the same equipment. It is possible to control various devices in a common part program and use CNC system for different laser technological processes, such as laser hardening of surfaces or laser cladding, without fundamental changes in the system architecture [16].

4. Conclusion

The CNC for hybrid technology greatly simplifies the manufacturing process and reduces the total manufacturing time for parts that need to use special finishing operations to provide high quality of their surfaces. The proposed methodology of building the control systems for hybrid equipment is based on a common multifunctional software solution. As a result, it reduces time and cost of developing control systems for complex machine tools and reduces the time to bring product to market [17]. The open CNC systems architecture combined with modern software development tools allows organizing control of various executive devices within a common part program, using the ability to connect external control modules.

Acknowledgements

This research was supported in part by Federal target programs “Scientific and Scientific-Pedagogical Innovation. Staffs of Russia” in 2009–2013 and "National Technological Base".

References

[1] Grigoriev S.N. Principles for creating a multifunctional numerical control system for process equipment based on a common kernel with an open modular architecture // Instruments and Systems: Monitoring, Control, and Diagnostics. 2011. №05. pp. 1-11.
[2] Moriwaki, T. Multi-functional machine tool. CIRP Annals - Manufacturing Technology, Volume 57, Issue 2, January 2008, Pages 736-749.
[3] Poppeova, V.; Uricek. J. & Bulej, V.: Trends in the Area of Multitasking Machine Tools, Chapter 19 in DAAAM International Scientific Book 2011, pp. 227-242.
[4] Martinov G.M., Martinova L.I. The analysis of numerical control systems presented at Metal-processing Technoforum 2009 International Exhibition, their novelty and features // Automation in industry. 2009. № 12. pp. 59–65.
[5] Lauwers B. Surface Integrity in Hybrid Machining Processes. Procedia Engineering vol. 19 2011. p. 241-251.
[6] Chih-Wei Chang, Chun-Pao Kuo An investigation of laser-assisted machining of Al2O3 ceramics planing. International Journal of Machine Tools and Manufacture, Volume 47, Issues 3–4, March 2007,Pages 452-461.
[7] Hongtao Ding, Yung C. Shin, Laser-assisted machining of hardened steel parts with surface integrity analysis. International Journal of Machine Tools and Manufacture, Volume 50, Issue 1, January 2010. pp 106-114.
[8] Nezhmetdinov R.A., Sokolov S.V., Obukhov A.I., Grigoriev A.S. Enhancement of numerical control systems' functionality for mechano-laser treatment control // Automation in industry. 2011. №5, pp. 49-53.
[9] K. Zimmer, D. Hirsch, F. Bigl: "Excimer laser machining for the fabrication of analogous microstructures", Appl. Surf. Sci. 96-98 (1996), 425-429.
[10] J.P.Wulfsberg, S.E.Hilpert, A.Ostendorf, and K.Samm, "Fundamentals of laser-assisted microforming," 1.Colloquium Processscaling, Bremen, pp. 1-8, 2003.
[11] Martinova L. I., Martinov G. M. Organization of Intermodule Interactions in Distributed CNC Systems. Models and Algorithms for Implementation // Mekhatronika, avtomatizatsiia, upravlenie. 2010. №11. pp. 50-55.
[12] Grigoriev S.N., Andreev A.G., Martinov G.M. Development prospect of cross-platform computer numerical control systems for high-tech equipment // Automation in industry. 2011. №5, pp. 3-8.
[13] G. M. Martinov, L. I. Martinova Trends in the numerical control of machine-tool systems // Russian Engineering Research. 2010. T. 30. № 10. C. 1041-1045.
[14] Martinov G.M. Current trends in computer control systems of technological equipment // Vestnik MSTU "Stankin". 2010. № 1. pp. 74–79.
[15] Martinov G.M., Kozak N.V., Nezhmetdinov R.A., Pushkov R.L. The principle of constructing a distributed NC system with open modular architecture // Vestnik MSTU "Stankin". 2010. № 4. pp. 116-122.
[16] Martinov G.M., Ljubimov A.B., Obukhov A.I. The Problem of Adaptation of PCNC Systems for Laser Engraving Machines // Mehatronika, avtomatizacija, upravlenie. 2009. № 1. pp. 59-62.
[17] Grigoriev S. N. Scientific and Technical Problems of Creation of the Modern Technological Systems with Numerical Program Control // Mekhatronika, avtomatizatsiia, upravlenie. 2011. № 4. pp. 19-26.