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VIRTUAL SIMULATOR FOR FIVE AXIS VERTICAL TURRNING CENTER IN PYTHON GRAPHICAL ENVIRONMENT INTEGRATED WITH OPEN ARCHITECTURE CONTROL SYSTEM

Abstract: *This paper proposes how to simulate five axis vertical turning center in open architecture software environment EMC2 (**E**nhanced **M**achine **C**ontroller). It was shown how to integrate functions of direct and inverse kinematics, way of modelling the components of virtual machine tool in the Python environment, their connection within the machine simulator that allows movement simulation in the function of NC machining program. Machine simulator is integrated in the software environment EMC2.*
Key words: *modelling, programming, simulation, five axis vertical turning center, EMC*

1. INTRODUCTION

Researches in a field of control multi-axis machine tools as manufacturing systems are becoming dominant in many research institutions dealing with development of numerical control systems. In many different areas simulators exists, so this idea is also realised in the field of multi-axis machine tools.

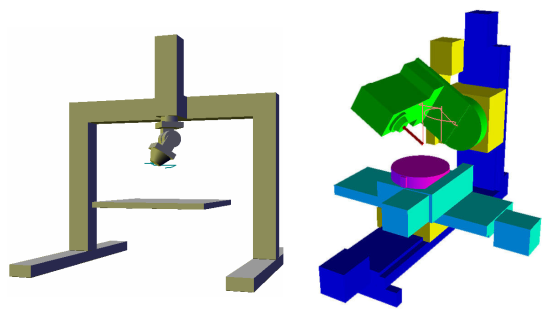
The introduction of open-source software package EMC (***E****nhanced* ***M****achine* ***C****ontroller*) [1, 2] and *AXIS* GUI (***G****raphical* ***U****ser* ***I****nterface*) [3], has dramatically improved development and availability to wide range of CNC user. New versions of the software brought significant improvements. With existing graphical environments, only possibility is to run tool path simulation. However, the idea is to create a virtual machine as a simulator, that will allow movement of complete machine in Python 3D environment and that can be integrated with EMC software. That way, any collisions that may occur during the execution of the program can be captured. With simulation of the tool path only there is no such possibility.

Integrating the virtual machine tool with EMC2 core, the simulator for programming, control and simulation, in virtual Python graphical environment were completed.

2. STATE OF RESEARCH

EMC2 software environment for machine tool and robot control are, in general, accepted by many. It has a great versatility. Ranges are from educational [4], to professional in sense of control large machine tools [5, 6, 7]. The fact that should not be ignored is that more and more new machine tools builders, as the basis for the development of its own CNC, use EMC2. Chinese machine tool builders are the leaders. In China there are very ambitious professionals who develop new control systems which are based on open architecture [8, 9].

During several years of presence on domestic and foreign software scene, EMC2 an open-source software system for machine tool control has gained a large number of users and those involved in its permanent development [1, 10, 11]. Examples of some realized multi-axis virtual machines are shown on Fig.1.



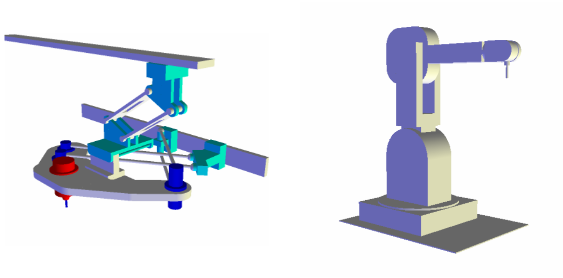
a) Portal five axis machine tool [10,11]

b) Five axis machine tool [10,11]

Fig.1. Virtual models of multi-axis machine tools

Our research and development in this area started three years ago, with configuration of control system for educational three-axis desktop parallel kinematics machine pn101_st V.1 [12] (Fig.2a). Successful realization of this project, continued with the implementation of control system for industrial robot Lola 50 as a reconfigurable multifunctional manufacturing system [7] (Fig.2b).

Alongside those control systems, virtual machines are developed on the same basis, as a support for programming and control of machines and in education of students [4]. First emerge the virtual model of a robot LOLA 50 (Fig.2b), as a result of the need for off-line programming system for reconfigurable manufacturing system based on the robot. The following implementation of virtual machines is achieved for the educational three-axis desktop parallel kinematics machine pn101_st V.1 (Fig.2a).



a) *pn101_st V.1* b) *LOLA 50*

Fig.2. Virtual models of machine tool and robot

3. CONCEPT OF 5-AXES VERTICAL TURNING MACHINING CENTER

Adopted concept of vertical five-axis turning center was founded by upgrading vertical three-axis turning center with two-axis head capable of milling, drilling and turning, Fig.3.

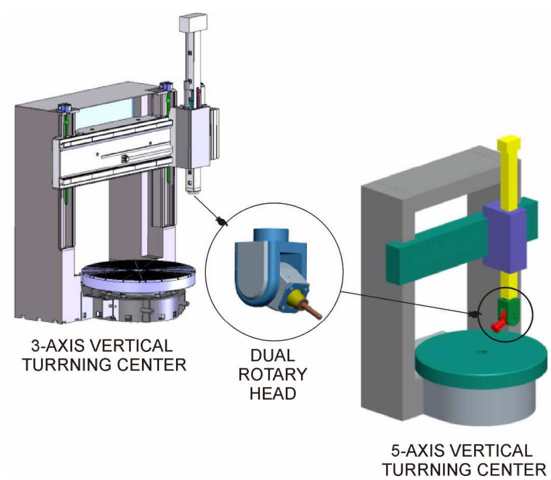


Fig.3. The concept of upgrading three-axis to five-axis turning center

In this way, five-axis machining is achieved. The first axis of milling head is collinear with Z-axis of machine. Rotating milling head around this axis to ±180° allows rotating the cutting tool in XY plane. Second axis of the milling head enables cutting tool tilting in relation to the horizontal axis. Each of these two axes has its own independent drive.

On the machine there is no movement along Y-axis, like one that exist on conventional portal milling machine. To achieve movement of the Y-axis, the base coordinate system of the machine must be fixed to the rotary table, Fig. 4. Composition of movement on all machine axes in accordance with inverse kinematics will led to Y-axis move.

This concept of the machine allows machining (turning, drilling, milling) of large, complex geometry, parts. This avoids the setup and clamping on different machines, and machining can be done in one setup on one machine.

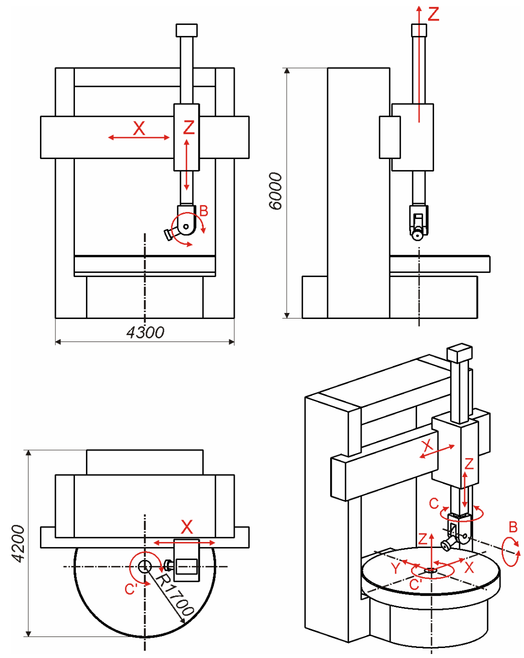


Fig.4. Concept of five-axis vertical turning center with coordinate system axes

4. STRUCTURE OF OPEN ARCHITECTURE CONTROL

The basic structure of applied open architecture control system is: PC as a base, CNC interface cards, a software-oriented CNC and a real-time operating system, Fig.5.

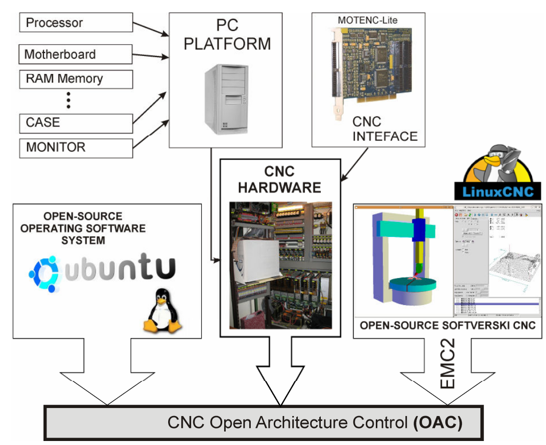


Fig.5. The structure of the developed concept – open architecture CNC on a PC platform

For the realization of the control unit for multi-axis machines it is necessary to provide a stable hardware platform, real-time operating system and driver software with appropriate performance. PC platform was chosen as a hardware platform, along with the compatible operating system for real time processing. Ubuntu Linux with real time extension (RTLinux) was chosen as a very reliable and widespread solution. This operating system fully meets the assigned criteria relating to time-critical processes of software CNC. The 1ms servo loop period of execution and 5ms for generation of new tool path interpolating segment along with timely execution not less important processes of lower priority and parallel, comfortable, work of user with less demanding application are the main criteria which are taken into account when building CNC hardware platform and operating system.

To complete a conception of control unit it is necessary to add an adequate CNC interface cards into a PC platform. PCI interface on PC motherboard was one of the main criteria for selection MONTEC Lite Cards. Two of these cards, which are attached to primary computer platform with a total of eight analogue outputs for connections to the frequency converters and eight square digital inputs for connection to the optical measuring systems. There is a multitude of digital inputs and outputs for connection to sensors and micro-switches of machine. This is more than enough to control five axis of auxiliary motion and one main drive of the machine.

Software oriented PLC is another element within the EMC2 software system. Software PLC is executed on the same hardware platform as software CNC. It is basically a program that is executed in parallel, concurrent, with other software components on the same hardware platform. PLC provides board of additional possibilities to the machine tool, such as control of tool-changer etc.

5. SIMULATOR OF VIRTUAL MACHINE IN PYTHON GRAPHICS ENVIRONMENT

Configuration of virtual model of vertical five-axis turning center is accomplished in the programming language Python. Algorithm for configuring model is shown in Fig.5. The modelling process of the virtual model boils down to programming the coordinates for the definition of elementary geometric bodies. To facilitate work, good practice is to model simplified model of machine in any CAD system, where one can easily download necessary coordinates to define primitives. Based on information from the CAD model simplified virtual model is programmed, it can be described using the primitives (Box, Cylinder ...) displayed in Fig.5. These primitives are grouped in a rotating or translation axes. It is important that all essential geometric parameters be correctly modelled, while the dimensions which do not affect the kinematics can be approximate. The programming should take into account the axis directions. They should be set according to the kinematics model established before. During the configuration of virtual models, one by one axis is programmed and immediately after checking must be done in order to prevent mistakes.

As a result one can get a virtual model of the machine in *Python 3D* environment that integrates in graphical interface *Axis* and control core of EMC2. In the window of virtual machine one can see moving segments of virtual machine according to control program (G-code) and a trace curve made by tool tip.

Virtual simulation is considered here to test and verify program before going to the real machine. Virtual simulation allows movement of modelled segments of turning center, with the tool at the end. Tool draws on the screen tool path, which is a result of the execution of program (G-code). All is done in a real time, in the same way as the real machine. This is very important especially when it is done for the first time for testing machine with a new control, or when one have a machine, and wants to perform testing and verification of the program and control.

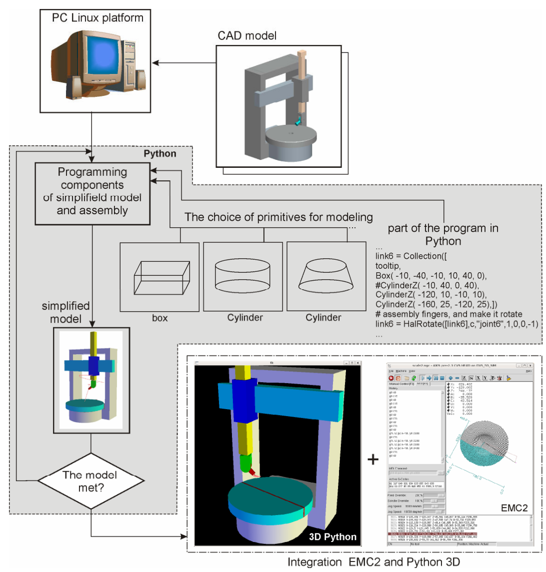


Fig.5. Configuration of a virtual machine in Python 3D environment and integration with EMC2 and Axis

6. OFF-LINE PROGRAMMING

Virtual simulation allows off-line programming with verification and testing on a remote site without machine engagement. Since there is a word about the real-time simulation of the machine, it can also be used for monitoring of machining operation from remote location. Working in the virtual environment is also suitable for training and education in programming of such manufacturing systems.

Programming of vertical five-axis turning center is similar with the five-axis milling machine with conception of axes XYZBC, whereby the programmer's habits do not change.

The first rehearsal with machining simulation of virtual model are realised by programming in Pro/Engineer environment. For obtaining a G-code the appropriate postprocessor is configured. Testing is done on a virtual machine of vertical five-axis turning machine, realised in the Python programming language, which is integrated with the Axis user interface. In Fig.6 is shown five-axis machining of complex surface in virtual environment.

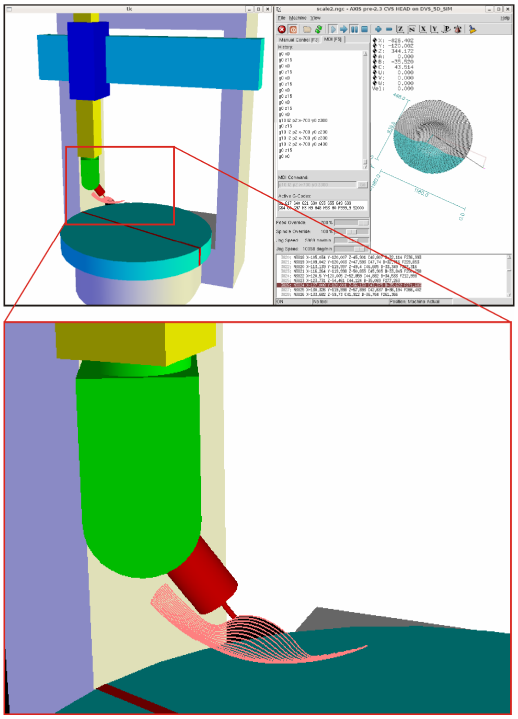


Fig.6. Five-axis vertical turning center as a virtual machine integrated with the environment AXIS

7. CONCLUSION

The main objectives of the presented research can be summarized in the concept of developing a control for CNC machine tools of specific configurations with integrated virtual simulator.

Development of virtual environments such as simulators for programming and simulation of machine tools during the machining is important because it allows off-line programming with verification and testing of the program. Working in the virtual environment is suitable in terms of training and education for programming of such manufacturing systems, especially in educational institutions in country, where there is chronic shortage of multi-axis machine tools. In this way, and without existence of resources, i.e., new machines, it is possible to receive training for their programming.

8. ACKNOWLEDGEMENTS

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