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TESTING AND PROGRAMMING MINI LABORATORY AND DESKTOP 3-AXIS PARALLEL KINEMATIC MILLING MACHINE

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Abstract: *This paper describes testing and programming methods for parallel kinematic machine based on mini laboratory and desktop 3-axis parallel kinematic milling machine (PKMM). The paper presents the IDEF0 methodology for developmentally testing of new machine tools, with an example of application of this methodology. Several test workpieces are machined in order to verify the developed control and programming system.*
Key words: *testing, programming, parallel kinematic machine*

Programiranje i ispitivanje mini laboratorijske stone troosne glodalice sa paralelnom kinematikom. *U ovom radu se opisuje ispitivanje i metodi za programiranje mašina sa paralelnom kinematikom, na osnovu mini laboratorijske i stone troosne mašine sa paralelnom kinematikom. Prikazana je i IDEF0 metodologoja za razvojno ispitivanje novih mašina alatki, sa primerom primene. Obrađeno je nekoliko test radnih predmeta u cilju verifikacije razvijenog sistema za upravljenje i programiranje.*
Ključne reči: *ispitivanje, programiranje, mašina sa paralelnom kinematikom*

1. INTRODUCTION

Previous experience in the field of PKMM and successfully developed first industrial prototype of vertical milling machine based on newly developed parallel mechanism is shown in [1,2]. As a result of the experience in developing vertical milling machine industrial-size prototype, we come to the conclusion that, based on the same mechanism, a low-cost mini laboratory and desktop educational 3-axis parallel kinematic milling machine can be developed as a help in the process of acquiring basic experiences in the field of PKM [3-8].

Compared to the first experimental industrial-size prototype milling machine, scaling factor 5 is adopted for the desktop machine, because the machine would be real desktop and would have five times smaller overall sizes and five times smaller workspace overall sizes, retaining all advantages of parallel mechanism which is used. The structure of the parallel mechanism, modeling approach, solving of inverse and direct kinematics, workspace and singularity analysis and control system of developed mini laboratory and desktop 3-axis PKMM, have been described in previous research [1-8].

Based on adopted concept and design parameters, the first low-cost desktop educational 3-axis parallel kinematic milling machine has been built and tested in our laboratory [5-8]. The first low-cost desktop educational 3-axis PKMM presented in [3-5] was physically realized and was named pn101_st V1. This paper presents a testing of new version (pn101_st V1.5) with small modifications that includes the protection cover as well as trunk for chip, Fig. 1.

Fig. 1. Mini laboratory and desktop 3-axis PKMM

Control system of parallel kinematic machine is much more complex than control system of traditional machines with serial kinematics, because it is necessary to solve inverse and direct kinematic problems. Advantage of this parallel mechanism is in the fact that inverse kinematic problem can be solved in an easy way [5,8]. The control system, for our machine, is based on PC Linux platform with real time extension and EMC (Enhanced Machine Controller) software system [9]. EMC was created by NIST (the National Institute of Standards and Technology) [10] and is free software released under the terms of the GPL (General Public License).

The paper structured as follows. Section 2 gives an overview of the programming methods for realized machine. Section 3 gives the description of the methodology for testing mini laboratory and desktop 3-axis PKMM. Section 4 describes machining experiments and program verification during the machine testing.

2. PROGRAMMIMNG METHODS

Current situation of programming method is based completely on the G code. Numerical control machine tools have evolved from simple machines with controllers that had no memory, driven by punched tape to today's highly sophisticated Computer Numerically Controlled (CNC) machine tools. Machine tools have changed radically, but the programming language has remained the same with G code programming (ISO 6983) [11].

This paper also presents programming methods for mini laboratory and desktop 3-axis PKMM as well as programming system based on G code. Mini laboratory and desktop 3-axis PKMM can be programmed using several different methods, (i) Manually programming; (ii) Conversational programming; (iii) Programming using the CAD/CAM system; and (iv) New programming method using the software STEP-NC Machine [6,12,13].

An open challenge, in the field of machine tool programming is the new programming method using standard known as STEP-NC. The development of new programming method is running, but is still an unfinished work [12-19]. STEP-NC is a new interface that has developed for exchange of information between CAD/CAM systems and CNC controllers. The STEP-NC provides CNC controller new opportunities that enables controller to receive high level of information from workpiece design. It allows bi-directional flow of data between CAD/CAM and CNC Machine Tools without losing information. STEP-NC does not describe the tool trajectories for specific CNC machine tool as G code does, but it provides a feature based data model. A STEP-NC file is not machine tool specific and can be used on various machine tool controllers [15]. Now, this method of programming can't be completely used, because the resources for that development are owned by several research centers. There are possibilities for application through two possible scenarios (SC1, SC2) which are described in [13]. This approach is an indirect application of this programming method on existing machines and available software.

3. METHODOLOGY FOR TESTING MINI LABORATORY AND DESKTOP 3-AXIS PKMM

IDEF0 is the method designed to model the decisions, action, and activities of an organization or system. It is useful in establishing the scope of analysis, especially for a functional analysis. IDEF0 is used to produce a "function model". A function model is structured representation of functions, activities or processes within the modeled system or subject area[4].

In this paper, functions of testing mini laboratory and desktop 3-axis PKMM, are described by using the IDEF0 diagram. This is a part of methodology of configuring new machine tools, which is described in details in [4,8]. A full decomposition of the activities in configuring new machine tools with an example of application of this methodology for mini laboratory and desktop 3-axis PKMM is summarized in Table 1.

A1. Design machine pn101_st V.1 and the establishment of the necessary model
A11. Selection and design of machine
components
A12. Project of a complete machine tool
A13. Configure family machine tools
A14. Techno-economics of machine tool
A2. Configuring Control for pn101_st V.1
A21. Control modeling for machine pn101_st V.1
A22. Integration of model control into EMC
A23. Simulation of CNC system in EMC
A24. Configuring virtual machine simulator
A25. Integration of control systems into EMC
A3. Analysis and simulation of the model
A31. Formation of the model for CAE and optimization
A32. CAE analysis
A33. Optimization of the model
A4. Make pn101_st V.1 and test work
A41. Development of special components and
subcomponents
A42. Assembly of machine tool
A43. Calibration of machine tool
A44. Testing and trial work of machine tool

Table 1. A full decomposition of configuring activities [4]

According to the IDEF0 methodology, by analyzing diagram A44 in details, we get the basic flow of activities shown in Fig. 2. The basic activities are: A441 – Direct measurement, A442 – Indirect measurement, A443 – Rating and/or determination of quality indicators and A444 – Correction and setting up mini laboratory and desktop 3-axis PKMM.

The basic activities for testing in A44 diagrams, are very important for the final verification for control and programming system of mini laboratory and desktop 3-axis PKMM, throughout trial run. A detailed plan of methodology for developmentally testing is shown in Fig. 2, and special attention is paid to indirect methods of testing (A442), that is relating to the testing of the working accuracy.

Indirect testing methods were realized on the mini laboratory and desktop 3-axis PKMM during its trial work. These include verification of the workspace [5, 8], positions of referent points, and machining several test workpieces.

4. MACHINING EXPERIMENT

Several test workpieces are machined in order to verify the control and programming system. The main goal of the experiments was to test capabilities of the developed prototype of mini laboratory and desktop 3-axis PKMM.

The first test is done to verify the positioning of tool tip during the drilling of properly spaced holes, as an indirect testing method and is shown in Fig. 3a,b.

The second test is done to verify control and programming system based on G code using manually programming method. Linear interpolation is very serious test for parallel kinematic machine. A linear move is perhaps one of the most difficult motions that parallel kinematic machine can achieve. Therefore a non-standard test workpiece with grid of slots is chosen [6].

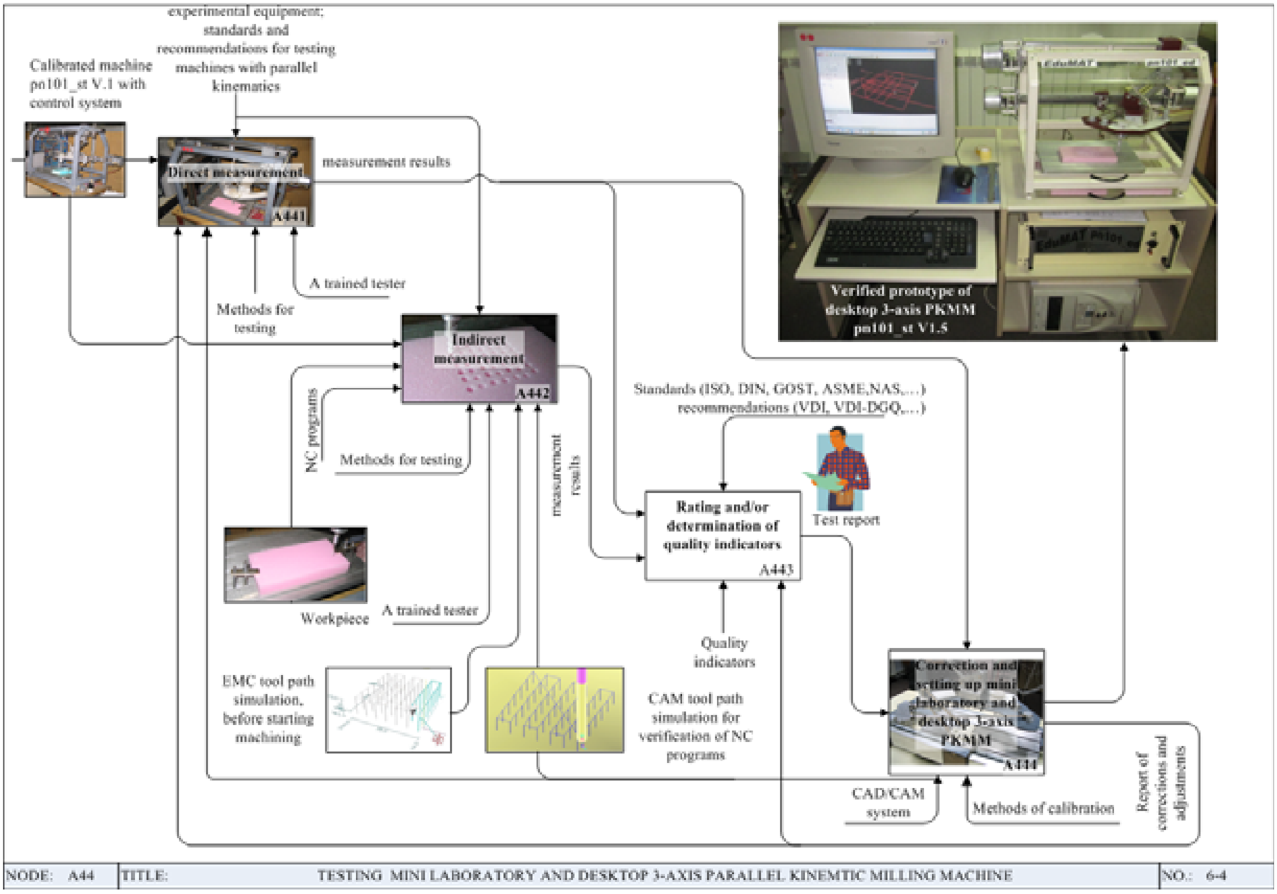
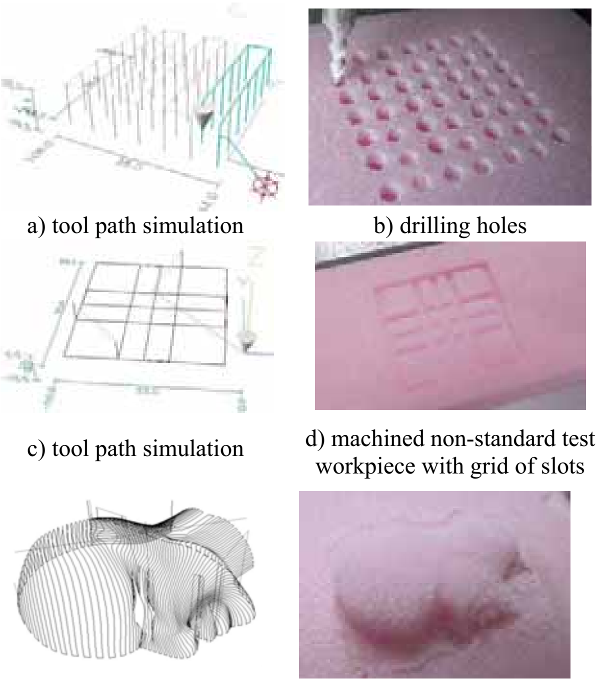


Fig. 2. The basic flow of activities for testing mini laboratory and desktop 3-axis PKMM



a) tool path simulation

b) drilling holes

c) tool path simulation

d) machined non-standard test workpiece with grid of slots

e) tool path simulation

f) machined workpiece having the shape of profile of human head

Fig. 3. First, second and third test workpiece machining

Tool path simulation and machined second test workpiece are shown in Fig. 3c,d. The third test is involved the machining of complex geometric esthetic surfaces, having the shape of profile of human head, using CAD/CAM system for programming. Fig. 3e,f shows 3 -axis machining of freeform surfaces having the shape of profile of human head.

The fourth test is done in order to verify current application of new method of programming based on STEP-NC. Figure 4 shows the example which refers to the machining benchmark workpiece based on the original STEP-NC program according to ISO 14649-11.

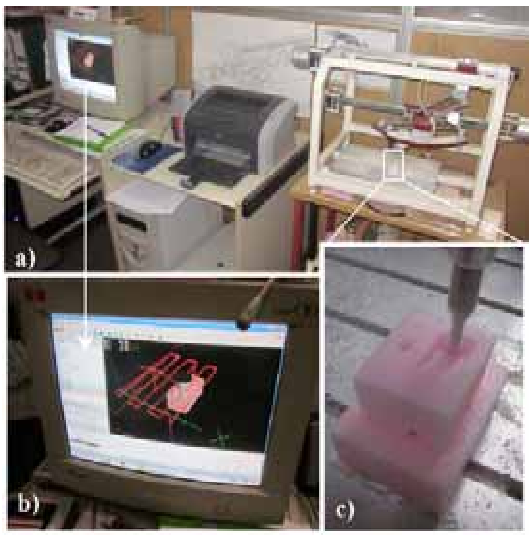


Fig. 4. Machining benchmark workpiece based on the original STEP-NC program according to ISO 14649-11

There are five machining working steps in this benchmark test. They are milling the top surface of the workpiece, drilling and reaming the hole, and rough and finish milling the pocket. Original STEP-NC program, according to ISO 14649-11 is translated using STEP-NC interpreter [20] in Canonical Machining Commands (CMCs), then these CMCs are translated into G code and then machining workpiece on the mini laboratory and desktop 3-axis PKMM is carried out.

Dimensions of workpieces are set according to the dimensions of machine workspace. Several test workpieces were made of styrofoam. In any considered case, a flat end mill tool (diameter 3 mm), was used.

For the prepared programs, the test workpieces are set in workspace boundaries correctly and workpieces are machined. We can state that these tests have successfully verified control and programming system of prototype of mini laboratory and desktop 3-axis PKMM.

5. CONCLUSION

This paper described the programming methods for mini-laboratory and desktop 3-axis PKMM in several different ways, such as manually programming, conversational programming, programming using the CAD/CAM system and new programming method using the software STEP-NC Machine. The methodology for developmentally testing of new machine tool and application of this methodology for testing of mini-laboratory and desktop 3-axis PKMM during its trial work were presented in this paper.

Developed desktop machine can machining soft materials, it is programmable in a common way, and it is fully safe for user-beginners, and represents a comprehensive and sophisticated educational machine tool.

Our future research will be focused on realized open architecture control system, that can download and directly execute programs in some of the STEP-NC formats for mini-laboratory and desktop 3-axis PKMM.

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