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CONFIGURING A VIRTUAL DESKTOP 5-AXIS MACHINE TOOL FOR MACHINE SIMULATION

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Summary: *This paper discusses the possibilities of application machine simulation and verification of the program before machining. Process of virtual machine configuring for machine simulation in CAD/CAM and VeriCUT environment is shown. Configured virtual prototypes are used for the verification of tool path as part of the off-line programming system, using machine simulation in the CAD/CAM environment. Verification of machining program, in G code, using machine simulation in the solid cutting simulation software VERICUT, are also described on examples.*
Key words: CAD/CAM, machine simulation, virtual prototype

1. INTRODUCTION

Configuring a virtual machine tools is a complex task which involves the use of huge spectra of methods, models, virtual prototypes, components and simulations. This is only one of the research challenges in order to realise a fully digitised model of the machine tool [1].

The kinematic structure and topology of machine tool are discussed in this paper, for the one desktop 5 axis milling machine. For this machine is configured virtual machine for simulation and verification of tool path and G code.

The simulation of machining process created in this paper includes the simulation of machine operation based on generated program in CAD/CAM system, and in Solid cutting simulation software VERICUT [2]. Machine simulation is important because: (1) Prevent CNC machine collisions; (2) Show machine operators what to expect from new programs; (3) Increase machining safety; (4) Enhance presentations and documentation with AVI simulations; (5) Train and education without using production time (or risking a crash of the real machine). The machine simulation using the solid cutting simulation software VERICUT can be seen in the papers [3-5].

The rest of the paper is organized as follows. Section 2 describes the conceptual model of the 5-axis machine tool under consideration in this paper. In Section 3, the configured virtual prototypes are used for the verification of machining

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program (tool path) and off-line programming system using machining simulation in the CAD/CAM environment. This was possible since the virtual prototype has the incorporated all kinematic joints. In Section 4, the configured virtual prototypes are used for the verification of machining program in G code using machine simulation in the Solid cutting simulation software VERICUT.

2. CONCEPT OF THE ONE DESKTOP 5 AXIS MILLING MACHINE

This paper deals with conception of desktop five axis machine tool with WCBVXYZT structure [6]. The verification of virtual prototype of desktop 5- axis machine tool is carried out using simulation of machining on virtual machine in CAD/CAM environment. For this work concept of one machine shown in Fig.1 was chosen. The basic machine is a 3-axis portal milling machine with structure VXYZ. Adding the two-axis tilting rotary table (B, C) in front of the basic machine, the machine becomes a 5-axis (S5D) with WCBVXYZT structure.

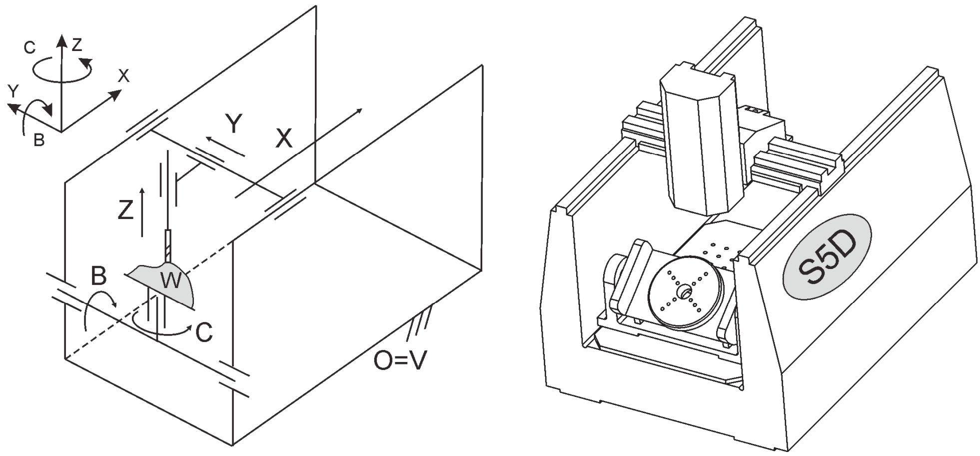


Fig. 1 *The conceptual model of 5-axis machine tool*

3. MACHINE SIMULATION IN THE CAD/CAM ENVIRONMENT

The configured virtual prototype is used for the verification of programming system in CAD/CAM environment by machining simulation based on generated tool path, which also includes machine simulation. This machining simulation is important in order to: (i) configure the off-line programming environment, (ii) verify program before machining, (iii) detect collision during program execution.

Machining simulation by running the program is possible thanks to the applied modeling of machine mechanism with all kinematic connections between the components, which allows the motion of a virtual model as a system of rigid bodies.

Fig. 2 shows a detailed virtual prototype of machine tool with all kinematic relationships.

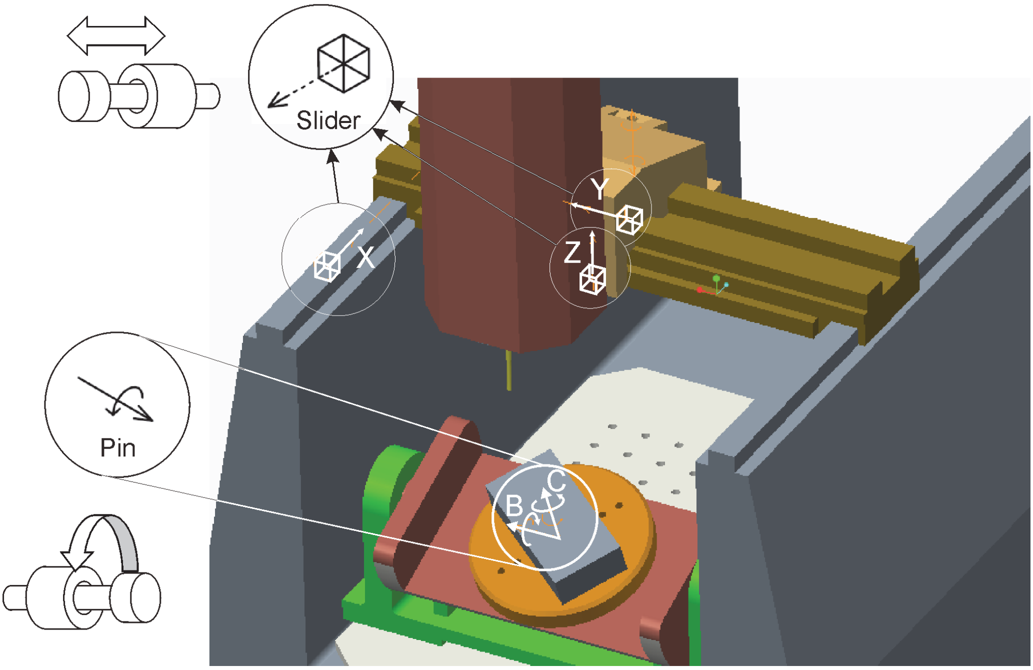


Fig. 2 *CAD model for the simulation of mechanism kinematics*

This assembly enables the motion of models in the range defined for each connection, which is of particular importance for the identification of possible collisions during the work of the machine mechanism.

Machining simulation of virtual prototype allows motion of movable segments with a tool at the end. Tool path is a result of the execution program obtained by programming using the CAD/CAM system PTC Creo 2 [8]. The machine is programmed in the programming format based on the G code (ISO6983).

For the workpiece shown in Fig. 3, we have adopted the zero point in the middle of the underside of the workpiece, with the coordinate axes X, Y, Z as has been used in the vertical 3-axis milling machine, marked as MACH_ZERO. The identical zero point (MACH_ZERO) exists on the machine (on the working table) on which the workpiece is placed, Fig. 3. Matching of these two coordinate systems is accomplished by setting the workpiece on the machine during the machining simulation. Fig. 3 also shows the simulated tool path on the workpiece, based on the generated CL file. Tool coordinate system is defined in the same way as workpiece coordinate system and marked as a TOOL_POINT.

During the simulation of tool paths, a complete prototype of virtual machine can be included into the simulation, with *Machine play* option. Example of machine simulation for virtual prototype S5D is shown in Fig. 4.

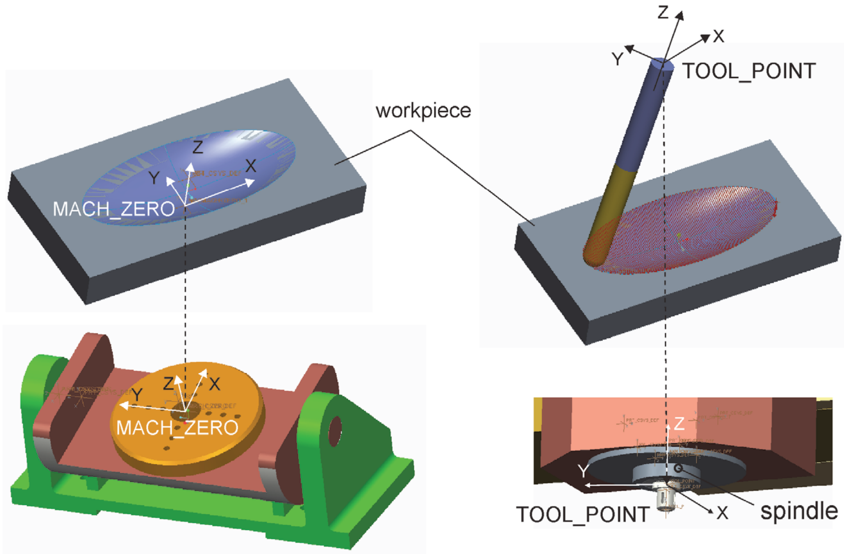


Fig. 3 *Coordinate system of the workpiece and tool with tool path simulation*

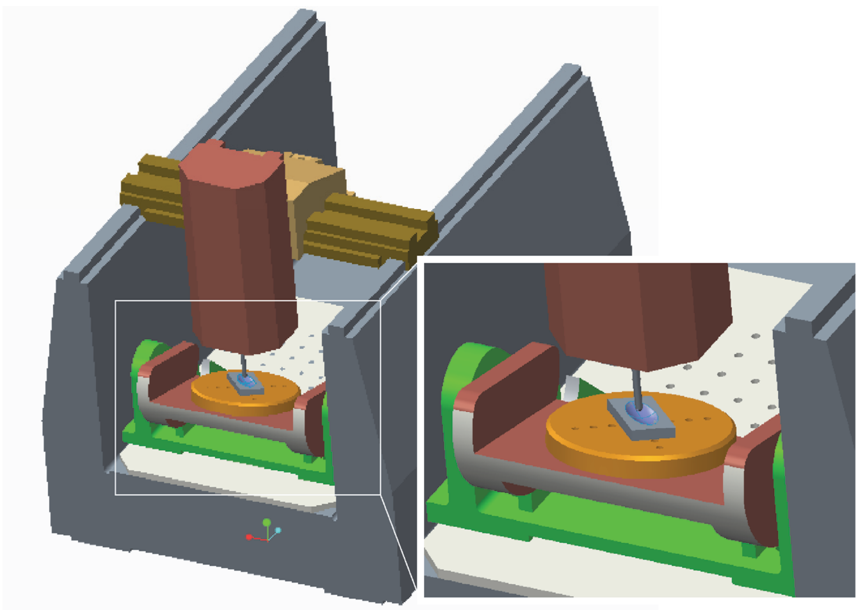


Fig. 4 *Machining simulation in the CAD/CAM system with machine play option*

4. MACHINE SIMULATION IN VERICUT SOFTWARE

Machine simulation is the safest and most cost-effective way to prove out 5-axis toolpaths.Solid cutting simulation software VERICUT is developed by CGTech [1]. This software operates with NC programs regardless the software type they were created by. It allows checking them, taking into consideration specific features of CNC systems and G-codes. Vericut is efficient together with PTC Creo: this allows using capabilities of both softwares' advantages to the fullest extent. Vericut can be directly called from PTC Creo menu and one can work with it either interactively or in the mode of batch processing of NC program files. Machine simulation solution allows realisation of realistic simulation of any CNC machine tool or its separate components, to use ready-made models from the extensive library (including lots of machines of the most well-known manufacturers), as well as to import models in IGES, STL and VERICUT formats.

The first step is to build the skeleton of the machine.The skeleton, or kinematic structure of the machine, describes how the machine's linear and rotary/pivoting axes are connected, Fig. 5. Every machine will have a BASE, TOOL, and STOCK components [7].

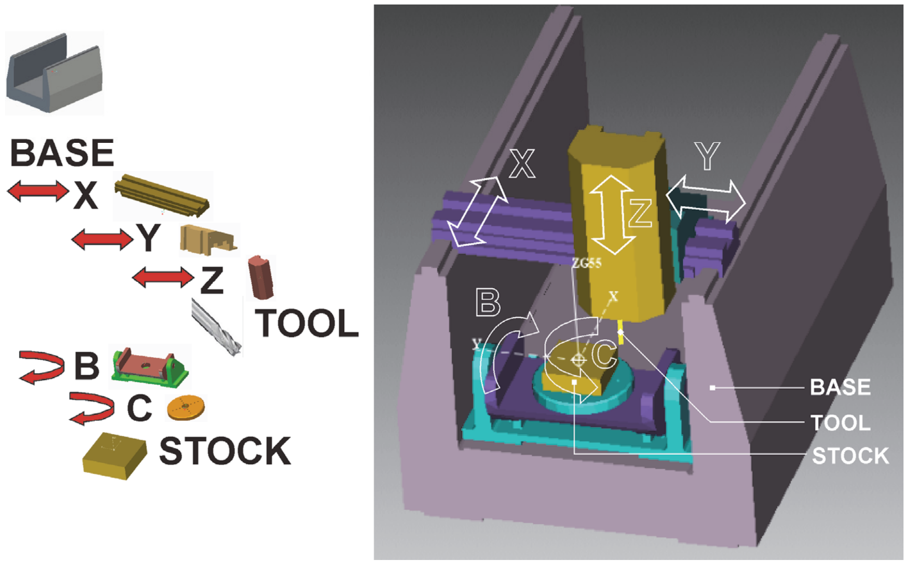
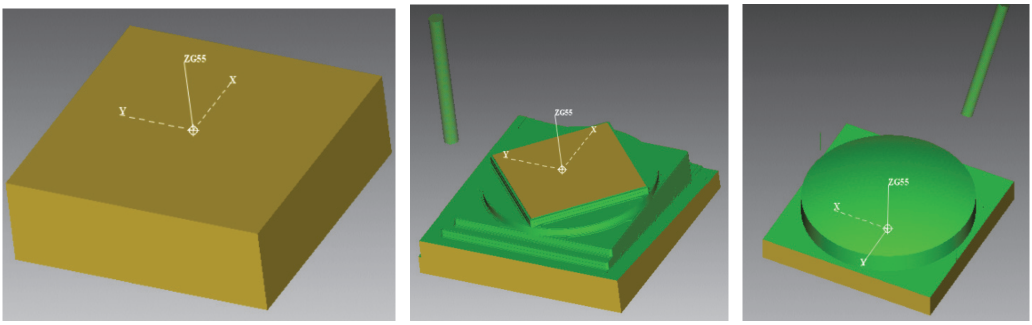


Fig. 5 *Kinematic component tree*

The kinematic component tree (shown to the left in Fig. 5) describes the machine (shown to the right in Fig. 5). The BASE is the first component. The X-linear axis is attached to the BASE. The Y-linear axis is attached to the X-linear axis. The Z-linear axis is attached to the Y-linear axis. The last component on this branch is the TOOL, attached to the Z-axis. The second branch s also attached o the BASE, starting with the B-rotary axis module. The C-rotary axis is is attached to the B-rotary axis, which in turn is carrying the STOCK,or workpiece.

This kinematic component tree is the most basic description of a machine, and represents a stripped-down skeleton of the machine. Most machine simulation software uses STL models as a default, for a configuring virtual machine for simulation. In this case, all basic components for machine configuration also are in stl format.

Workpiece, the test workpiece according to the NAS979, and second test workpiece with spherical surface for 5-axis machining, are shown in Fig. 6.



a) Workpiece b) NAS 979 c) Test workiece

Fig. 6 *Material removal simulation*

In this paper machining simulation in software Vericut is conducted based on G code, which is derived from the CAD/CAM system PTC Creo, with appropriate postprocessor. An example of machining simulation in Vericut software, for a given workpieces from Fig. 6, is shown in Figs. 7 and 8.

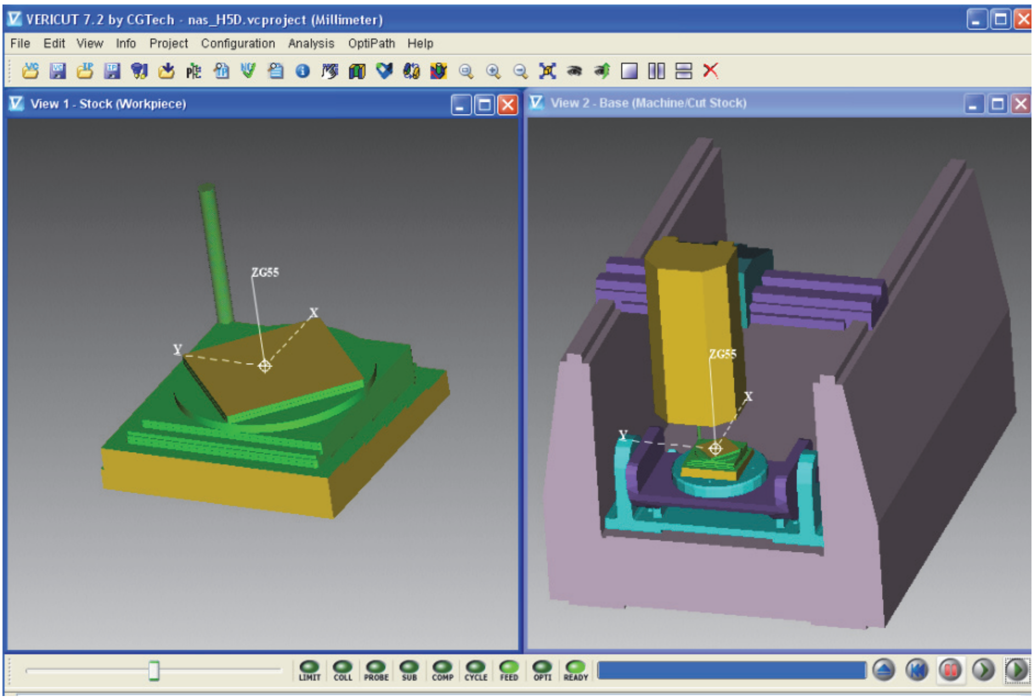


Fig. 7 *Material removal simulation with machine simulation for 3 axis machining*

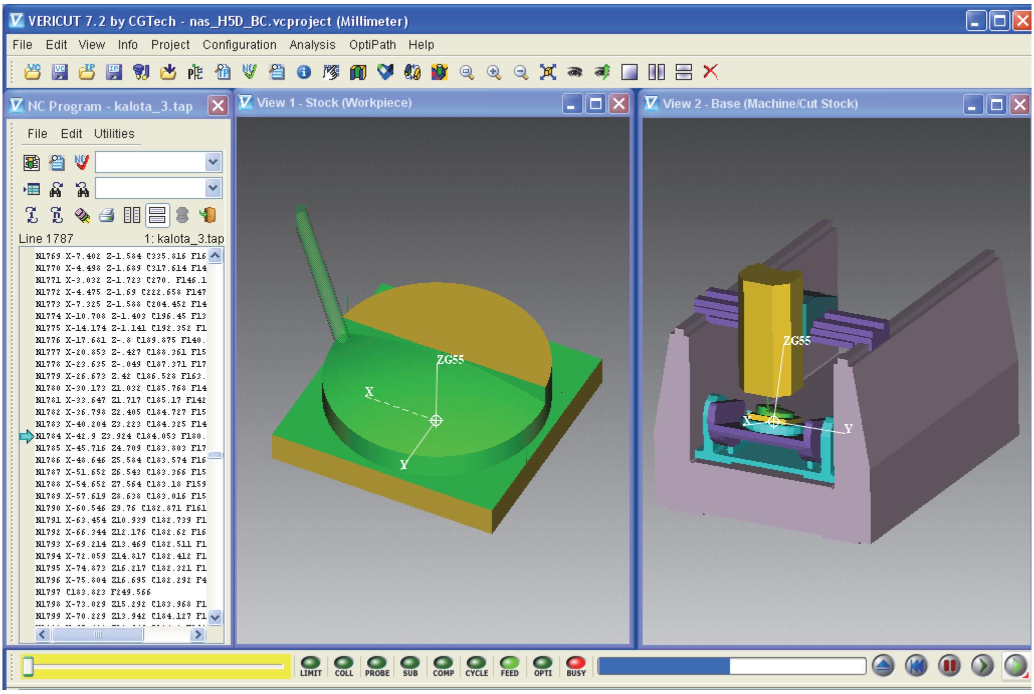


Fig. 8 *Material removal simulation with machine simulation for 5-axis machining*

Based on the realized simulations of machine virtual prototypes according to the running programs in G code, we haven't noticed any collision between the machine elements during program execution. Accordingly, we can state that these tests have successfully verified programming system and program in G code. For the prepared program the workpiece is set in workspace boundaries correctly and workpiece machining can be done without collision.

5. CONCLUSION

Nowadays, machining simulation plays an important role in modern manufacturing. There are many benefits to machine simulation, and one of the most important is testing program for machine, without pressure. Crashing machine on the computer screen is not a big problem, whereas crashing a real machine is catastrophic.

The process of setting up machine simulations is very similar to setting up a real machine. The part must be placed in the machine in the correct orientation.

Machine simulation, for tool path (CLF) and G code verification, on specific examples, are shown in this paper.The generated G code, are further verified using the solid cutting simulation software VERICUT. In further researches activities development of configuring virtual machines integrated with the control system is planed.

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