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TURNING MACHINE SIMULATION FOR PROGRAM VERIFICATION

Abstract: *In this paper we discuss the possibilities of application of turning machine simulation and verification of the program before machining. We present the process of new virtual lathes configuring for machine simulation in CAD/CAM environment. Configured virtual lathe is used for the verification of tool path as a part of the off-line programming system, using machine simulation in the CAD/CAM environment. The implementation of developed virtual machine and simulation is presented using a workpiece example. For this test part we have verified machining program using the material removal simulation, and carried out real world machining.*
Key words: *CAD/CAM, turning machine simulation, program verification*

1. INTRODUCTION

Nowadays, machining simulation plays an important role in manufacturing. Machine simulation is the safest and the most cost-effective way to verify tool paths. There are many benefits of machine simulation, and one of the most important is safe and time unlimited testing of machining program. Crashing machine on the computer screen is not a big problem, whereas crashing a real machine is catastrophic [1]. Configuring a virtual machine tool is a complex task which involves the use of huge spectra of methods, models, virtual prototypes, components, and simulations [2].

Machine simulation is an indispensable tool during programming of machines. It gives enormous possibilities in alternatives' testing and enables generation of not only accurate, but also most effective programs. Different cutting strategies, tools and fixtures can be tested in development phase until optimal solution is achieved. All of this is carried out off line on virtual machine, at computer desk, while the current job is in progress on real world machine. Thus, machine simulation is not used only to find errors in the code [1]. It offers many advantages:

- Programming errors are detected immediately.
- During program simulation actual machining time is calculated, and production effort can be estimated more easily.
- Collision checking with actual tools, tool holders and fixtures and machine geometries.
- Workpiece can be programmed and optimized while the current production process on the machine is in progress; developed program can be implemented on the machine immediately.
- Shorter setup times.
- Can be used for training and education.
- New machines can be programmed without any risk.

Program verification process includes the following simulations: toolpath simulation, machine simulation and material removal simulation.

Verification can be carried out based on the CLF (Cuter Location file) or based on the G code.

In this paper we describe the methodology for program verification on lathes. This methodology is implemented on the lathe TCN410-echoENG (Fig.1) for verification of tool path as a part of the off-line programming system, using machine simulation in the CAD/CAM environment.

Fig. 1. TCN410 CNC lathe – (echoENG)

Using basic modules and other components, such as CAD data for the real machine, the machine manufacturer or CAM system manufacturer can create a virtual machine that looks like the real machine as closely as possible [1]. On the other hand, when virtual machine is not provided by manufacturers, the user can develop virtual machine himself, as will be presented in this paper.

The rest of the paper is organized as follows. In Section 2, methodology for program verification on CNC lathes is proposed. Section 3 presents turning machine simulation. In Section 4, one workpiece is machined to experimentally verify the methodology for turning simulation, program verification and configured postprocessor.

2. METHODOLOGY FOR PROGRAM VERIFICATION ON LATHES

Methodology for program verification on lathes will be described using IDEF0 diagrams. IDEF0 is a method designed to model the decisions, actions, and activities of an organization or a system. It is useful in establishing the scope of an analysis, especially for a
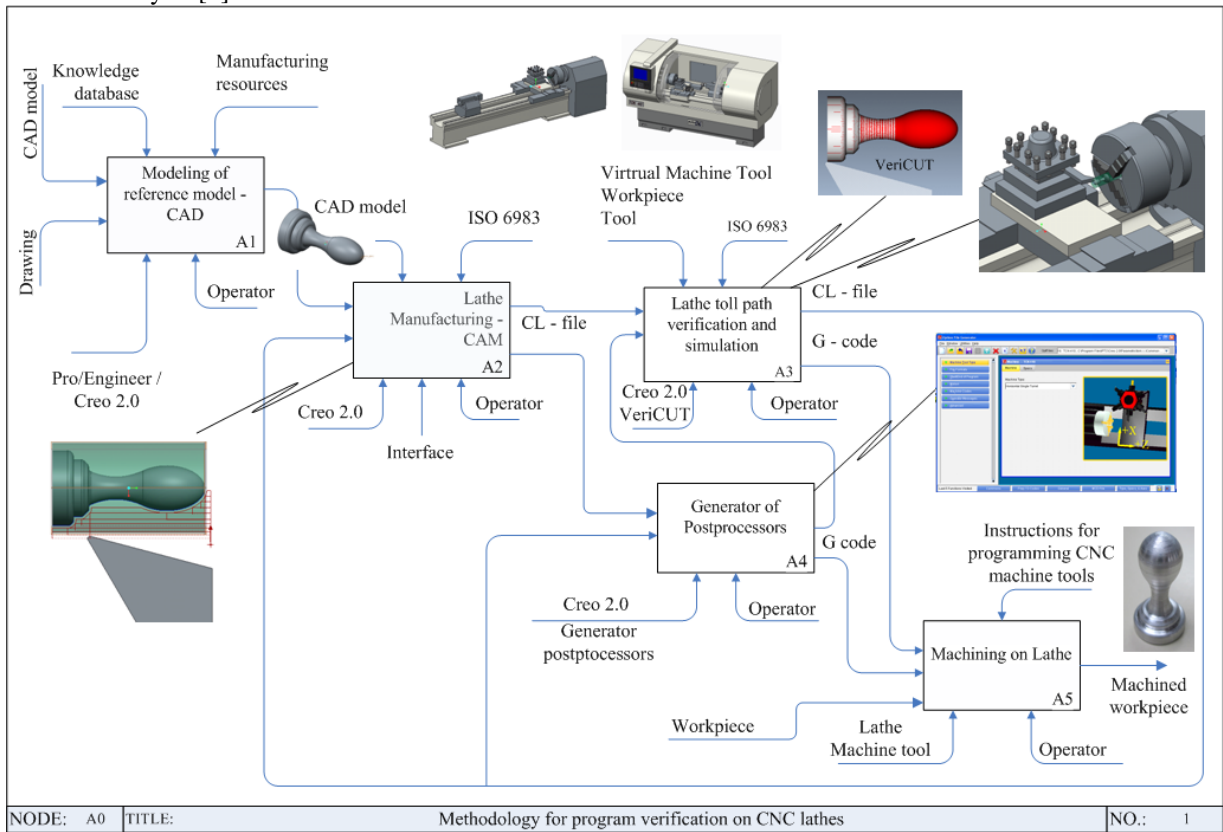
functional analysis [3].

Fig. 2. Basic flow of activities for methodology for program verification on CNC lathes

IDEF0 is used to produce a "function model". The function model is a structured representation of the functions, activities, or processes within the modeled system or subject area. This paper describes the function of turning machine simulation for program verification, using the IDEF0 diagram. Inputs for this methodology can be drawings or CAD model, while the output is machined workpiece. Based on these inputs, preparing reference models for the off-line programming, tool path, and G code are obtained. Verification of G code is carried out by using toolpath simulation, material removal simulation, and machine simulation. Lathe is programmed in G code according to the standard ISO6983.

IDEF0 diagram presented in Figure 2 describes the basic flow of activities (methodology) for program verification on lathes (Fig. 2). The basic activities are: A1 - CAD, A2 - CAM, A3 - Postprocessors, A4 – Tool path verification, and simulation and A5 - Machining. Input for activity A1 is drawing or CAD model that creates reference model for activity A2 (CAM). When the output from activity A2 is obtained (CL-file), it is verified within activity A3 using tool path simulation, material removal simulation and machine simulation. If some errors and collision are identified during the simulation, the activity A2 repeats until CL file is verified. Verified CL-file is an input for the postprocessing activity in the A4. Postprocessor is configured using the postprocessor generator in the CAD/CAM system Creo [4]. In our case study we used 2-Axis Lathe. Obtained G code can be forwarded to the activity A3 to verify the tool path or can be forwarded directly to the machine. After verification of the program in G code, we can safely pass over to the activity A5, where the machining is achieved on CNC lathe, without additional testing that exists on the machine.

3. TURNING MACHINE SIMULATION

Machine simulation by running the program is possible due to the application of machine mechanism modelling with all kinematic connections between components. That allows the motion of virtual model as a system of rigid bodies. Figure 3 shows a detailed virtual model of lathe mechanism with all kinematic relationships between moving components being defined. Slider conection is used for the movement of two sliders (Apron-Z and cros slide-X).
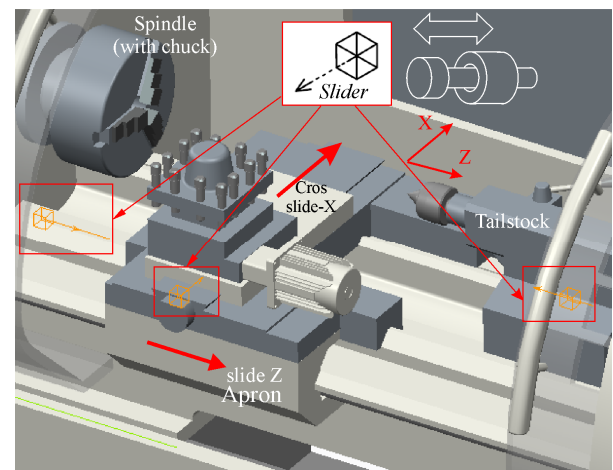

Fig. 3. CNC Lathe machine simulation

Such assembly enables the motion of the model in the range defined for each connection. It has the particular importance for the identification of possible collisions during the operation of the mechanism. Machining simulation of virtual model allows motion of movable segments, with the tool at the tool post.

On the screen, one can see the tool path which is a result of the execution program, created by programming using PTC Creo CAD/CAM system [4]. First of all, it is necessary to prepare a Reference CAD model of the workpiece (Fig. 4), which is used to verify off-line programming system for 2-axis CNC lathe.
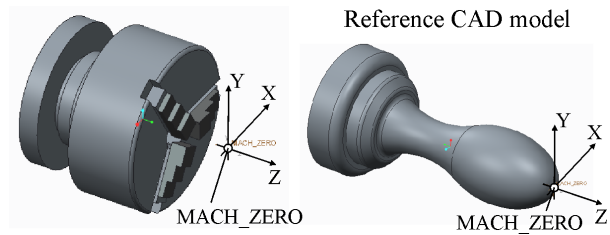

Fig. 4. Coordinate system MACH_ZERO

The identical zero point (MACH_ZERO) exists on the lathe (on spindle with chuck) and on workpiece (Fig.4). Matching of these two coordinate systems is done by setting the workpiece on the machine during the machining simulation.

Tool coordinate systems, on the machine, are marked as a TOOL_POINT. Matching of the tool coordinate system on the tool and on the machine (Tool post), results in setting of the tool into the tool post during the simulation process. Successful simulation is possible if the kinematic connections are correctly defined, as shown in Fig. 3.

After the programming completion, verification of the CL-file is achieved by simulating the tool path, Fig.5.
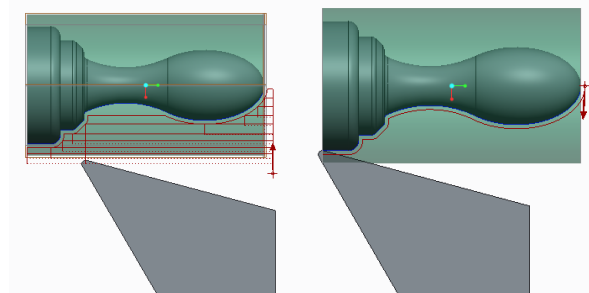

Fig. 5 .Tool path for turning

The TCN410 CNC lathe (echoENG) which is installed at Faculty of Mechanical Engineering in Belgrade, is used for programming and experiment. This lathe is fully modeled in CAD/CAM environment (PTC Creo), with all kinematics joints, in order to be able to include virtual machine model into machining simulation (Fig. 6). During the tool path simulation, complete CAD model of virtual machine can be included into the simulation, with Machine play option, in PTC Creo CAD/CAM system. The completed tool path simulation can be simulated by using rendered solid model of the machine, including fixtures and workpiece. Example of verification by machining
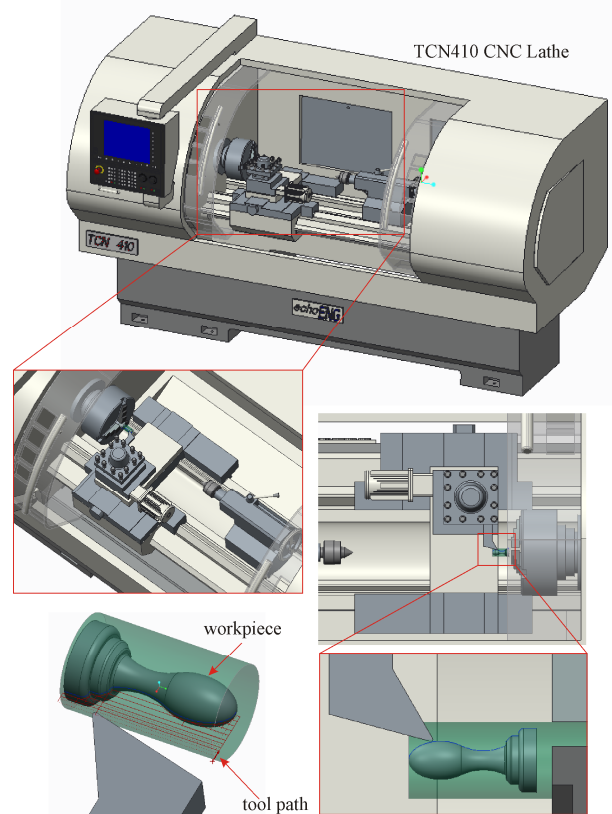
simulation is shown in Fig. 7.

Fig.6. Turning Machine simulation

CAD/CAM system enables: toolpath simulation (Fig.5), machine simulation (Fig.6) and material removal simulation – NC Check [5] (Fig. 7).
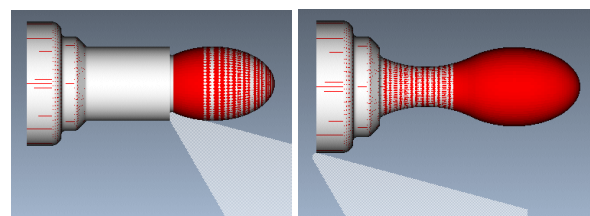

Fig. 7. NC-Check-material removal simulation

After the simulation process is completed, the postprocessing follows. The postprocessor is configured for the TCN410 CNC lathe by using the postprocessor generator from the PTC Creo CAD/CAM system (Fig. 8).
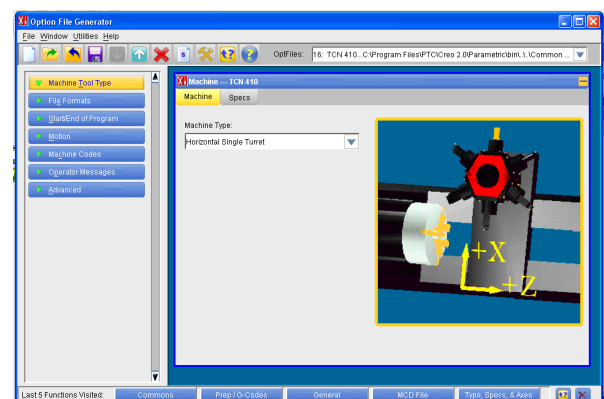

Fig.8. Postprocessor configuring

4. MACHINING TEST

To verify methodology for turning simulation, program verification, and configured postprocessor, we have machined one example of workpiece. Figure 9 presents a screen view of tool path verification on Simens Simumerik 808D control unit. After this final verification we can start safely with program execution on CNC lathe.
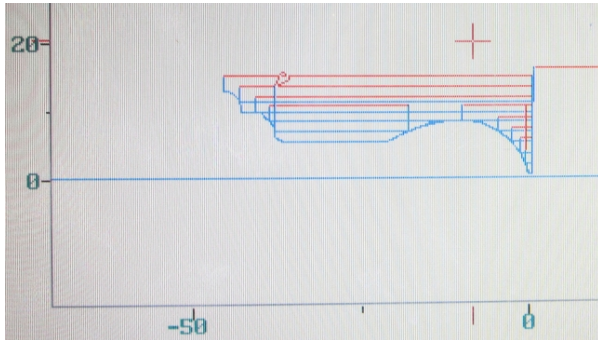

Fig. 9. Program simulation on Simens Sinumerik 808D

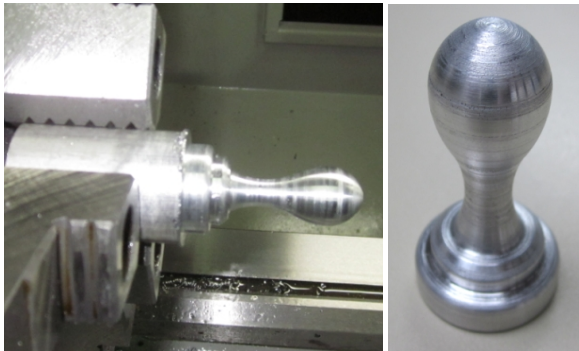The workpiece from Fig. 4, is machined on the TCN410 CNC lathe and it is presented in Fig. 10.

Fig. 10.Machined workpiece

This experiment confirmed that the proposed methodology for program verification which includes all kinds of simulation and configured postprocessor can be directly used by CNC programmers and operators. This is only one of the research challenges in order to realize a fully digitized model of the machine tool.

5. CONCLUSION

This paper presents a methodology for successful establishing of virtual machining environment for off-line programming within a CAD/CAM system that enables tool path simulation, material removal simulation, and machine simulation including the movement of machine parts. Chosen environment that fully meets all requirements is PTC Creo.

At present, machining simulation plays an important role in manufacturing, and this paper presents an integration of the off-line programming and machine simulation in CAD/CAM system Creo. Program verification is established by machining simulation in CAD/CAM system, where the machine model is working by the running program.

Off-line programming and simulation is very important for increasing the quality level of programming and program verification for CNC lathe.

Off-line programming allows multiple part program verifications, and after such verification part program can be immediately executed on the machine. Further research needs to be related to the applicability of the new method of programming known as STEP-NC [6], for CNC lathes.

6. REFERENCES

[1] Apro, K.: *Secrets of 5-axis machining*. Industrial Press Inc., New York, Printed by Thomson Press India Limited, 2008.

[2] Altintas C., Brecher M., Weck M., Witt S.: *Virtual machine tool,* CIRP Annals-Manufacturing Technology, vol. 54, No.2, p.p. 115-138, 2005.

[3] Kim, S.H., Jang, K.J.: *Designing performance analysis and IDEF0 for enterprise modelling in BPR*, International Journal of Production Economics, vol. 76, No.2, p.p. 121-133, 2002.

[4] PTC Creo, from, *http://creo.ptc.com,* accessed on April 2013

[5] VeriCUT, from *http://www.cgtech.com*, accessed on March 2015

[6] Zhang, X., Liu, R., Nassehi, A., Newman, S.T.: *A STEP-compliant process planning system for CNC turning operations*, Robotics and Computer-Integrated Manufacturing, vol. 27, p.p. 349–356, 2011.

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