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CONTRIBUTIONS REGARDING THE USE OF A CAM SOFTWARE SOLUTION IN MULTI-AXES MACHINING

Gabriela MURESAN, Liviu MORAR, Radu-Eugen BREAZ

Abstract: *Manufacturing processes are nowadays unfolded on numerically controlled machine-tools using CAD/CAM techniques. Simulations modules are available in any commercially available CAM software package The 2.5D and 3D milling processes require only the simulation of the relative movements between the tool and the part. However, for multi-axe machining, for an accurate simulation, it is necessary to use an geometric and kinematic model of the machine-tool. The paper presents the process of building such a mode for a five-axis machining center.*

Key words: *CAM, CNC, milling, geometric and kinematic model, multi-axes machining, simulation*

1. INTRODUCTION

Numerically controlled machine-tools (NCMT) are widely used for machining processes, such as milling, turning, cutting, electro-discharge machining and many other processes.

The milling process is one of the most common machining processed performed on NCMT.

Over the last decades, the programming of the NCMT has been based on a conventional language stipulated by ISO 6983, or otherwise known as G-codes [1]. For simple parts, the machining code, consisting of a list of above mentioned G-codes can be issued manually, by a trained programmer. However, nowadays CAD/CAM techniques are used in order to obtain complex and accurate parts. A schematic flowchart of the CAD//CAM techniques approach is presented in figure 1.

The first step involves the generation of three-dimensional (3D) model of the proecessef part using a general-purpose CAD program, such as Solidworks, CATIA, Siemens NX, Geomagic Design, Inventor.

The pre-processing stage involves the calculation of the geometric and technologic parameters of the process.

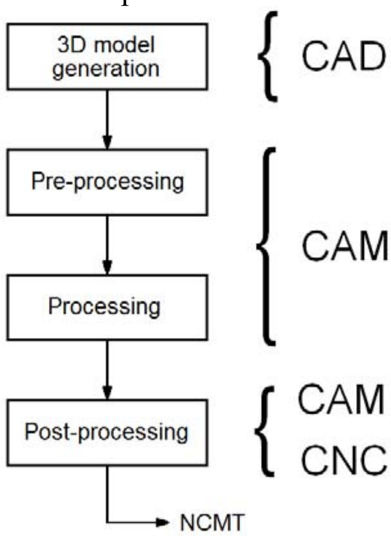

Fig. 1. CAD/CAM flowchart

This stage has some inputs, which also may be considered as constraints [2], such as the operation type (turning or milling), the available tools, the maximum allowable forces, the maximum thickness of the chip, the size of the machine-tool workspace and some outputs such as the tool selection, the processing toolpaths and the cutting regime.

The processing stage involves the issuing of the commands for manufacturing the part, block by block, as a file, usually called CLDATA file (cutter location data).

The CLDATA file contains the necessary information about the cutter location and orientation data, in order to drive the tool on the processing toolpaths The inputs for this stage are the type of command (linear of circular interpolation), the material properties and the detailed geometry of the tool.

The outputs are the values of the movement increments for each axis and the directions and senses of the movements. Also, the tool life is taken into consideration in order not to be exceeded.

The post-processing stage is dedicated to the adaptation of the commands within the CLDATA file to certain CNC equipment, as a specific CNC code, usually in as G-code language [3].

This stage is performed using separate software modules, build as stand-alone programs, called post-processors which are provided by the commercial CAD/CAM software vendors for each type of CNC machines and equipment, usually organized in post-processors libraries.

The pre-processing and processing stage are performed by means of the CAM software package and are independent form the CNC equipment used for manufacturing the part, while the post-processing stage, also performed within the CAM software, is highly dependent of the CNC equipment.

2. MULTI-AXIS MACHINING

Usually, simple trajectories which follow the contour curves of the part are used in operations. The contour curves, are obtained by cross-sectioning the 3D model of the part with horizontal planes, equally spaced on Z axis. For example, for a hemispherical part, the punch will be driven on a circular trajectory in the horizontal plane, which will be also moved on vertical direction with a corresponding radius reduction on each vertical step.

This approach is called 2.5 D milling and is suitable for the part presented in figure 2.

Another type of milling strategy involves simultaneous movements on three axes (X, Y, Z) in order to generate the shape of the part. Of course, not every movement will involve all three axes, but most of them.

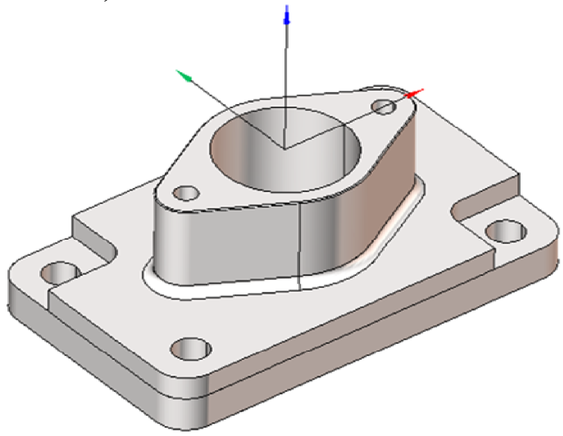

Fig. 2. Part suitable for processing by 2.5 D milling

Also, it is possible to mill some surfaces using movements which involve only simultaneous movements on X and Y axes, while other surfaces will be processed using simultaneous movements on Z and Y axes. However, due to the fact that for the same part the toolpaths are lying in perpendicular planes means that these operations may also be considered as 3D milling.

All the operations are specific for 3D milling approach and are suitable for the part presented in figure 3.

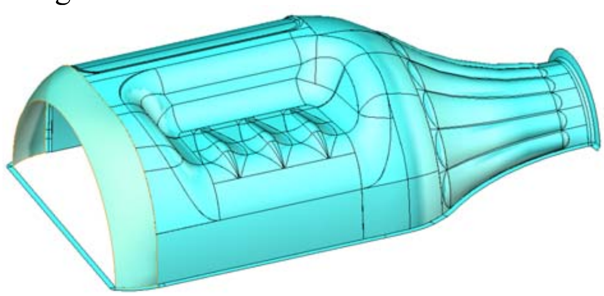

Fig. 3. Part suitable for processing by 3D milling

For complex parts, (e.g. turbine blades and turbine wheels, propeller blades) beside the movements on the translational axes X, Y, Z, also rotational movements on A, B, C axes are involved during the machining process.

If the translational and rotational movements are performed simultaneously, this approach is called 4D or 5D milling, depending of the number of axes which are moving simultaneously. 4D and 5D milling, also called multi-axis machining is unfolded on CNC machine-tools with very complex structure and kinematics. A part suitable for 5D milling is presented in figure 4.

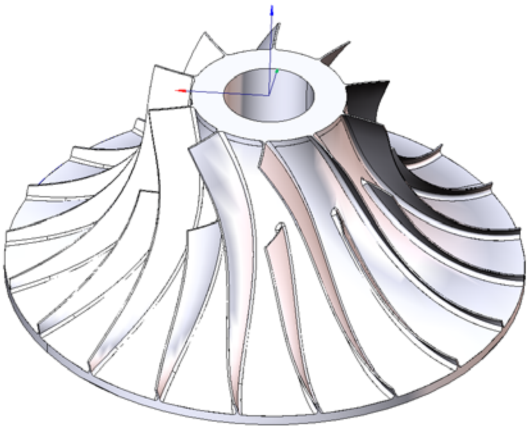

Fig. 4. Part suitable for processing by 5D milling

3. SIMULATING THE MILLING PROCESS

The simulation of the machining process, before running the NC code on the machine-tool is very important, taking into consideration the complexity of it and the costs linked to machining errors, which can lead either to dimensional and shape errors on the pars or even to damages at the machine level, due to collisions [4].

All the commercially available CAD programs also include a simulation module. Some of these modules are only able to simulate the trajectories of the tools (toolpaths) while others are are also able to simulate the material removing process (cutting).

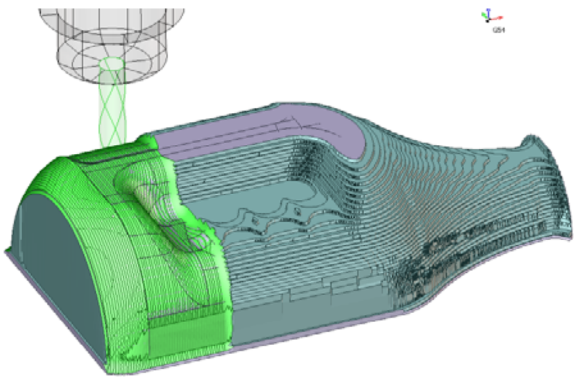

Fig. 5. Screenshot from a simulation of a 3D milling process

For 2.5D and 3D milling, normally only the relative movements between the tools and the part are simulated. For such processes, there is no need to take into consideration the movements of the mobile elements of the machine-tools (such as slides, rotating and/or tilting tables). Figure 5 presents a screenshot from a simulation process.

However, for 4D and 5D milling processes, due to the complexity of the movements involved in the process, collisions may occur between the tool and the part, but also between the mobile elements of the machine-tool. Consequently, an accurate simulation process needs to use a geometric and kinematic model of the CNC machine-tool, in order to take into consideration all possible movements involved in the process.

Some of the CAM software packages include such geometric and kinematic models of the most common machine tools. However, machine-tools builders are launching very fast new models on the market, so it is practically impossible to include their models in the CAM software. In order to address this problem, some CAM software packages include special modules (internal or external) which allow the user to build the geometric and kinematic model.

4. THE KINEMATIC AND GEOMETRIC MODEL OF OKUMA MU-400VA MACHINING CENTER

The OKUMA MU-400VA machining center is a new model of a five-axis vertical machining center built by Okuma company, presented in figure 6.The five axis of the machine are grouped in there translational axis X, Y, Z and two rotational axis, A and C.

The machine is able to perform simultaneous movements on all five axes.

The software package used during this research was SprutCAM, general purpose CAM software, made by Sprut Techology JSC. It can be used for the automated generation of NC program for milling, turning, EDM, laser and plasma cutting. The program also supports machines with two processing units (turning and milling).

The main objective of this research was to build the geometric and kinematic model of this machine-tool, using as the MachineMaker module [6].MachineMaker is an external module of the SprutCAM software package, which allows the user to build such models.

The flowchart of building geometric and kinematic models for multi-axes CNC machine tools is presented in figure 7.

Fig. 6. The OKUMA MU-400VA machining center

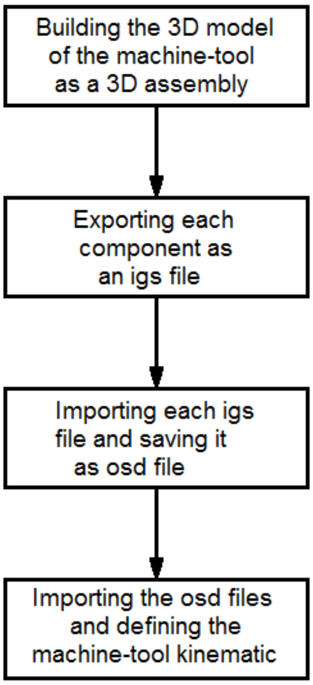

Fig. 7. The flowchart of building geometric and kinematic models

The first step involves the build of the 3D model of the machine tools as a 3D assembly, using a general purpose CAD program. It is important to notice that only the main components of the machine were considered for the model of the machine For example, such components were the machine frame, the slides, the tables, and the guideways.

Any elements which lie inside the machine frame (driving systems, ball screws, transducers)and cannot interfere with the movements of the machine slides were not taken into consideration.

The 3D model of OKUMA MU-400VA five axis machining center is presented in figure 8.

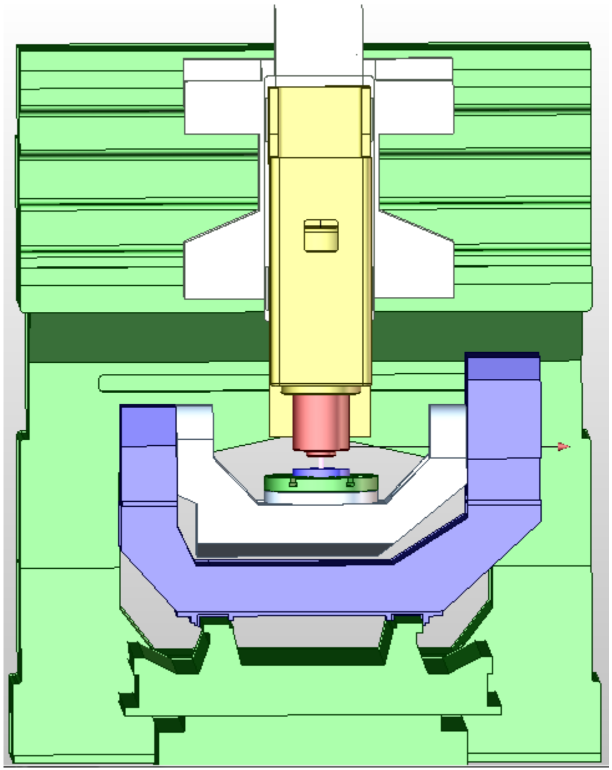

Fig. 8. The 3D model of OKUMA MU-400VA machining center

After completing the first step, the next one involves the export of each component of the assembly as an igs file. This second step is also performed using the CAD program. This step is required because igs format can be read by most of the CAM software packages

The third step is based on the import of the igs files in the SprutCAM core program [7] followed by their export in osd format. This step is necessary because the MachineMaker modul works only with this file format.

The fourth step, which is the most important one, is performed in MachineMaker and is based on the reconstruction of the machine model from the osd files, while defining the kinematic of the machine.

For each mobile element of the machine, the user has to define the axes along (for translational axes) or around (for rotational axes) the element is moving. Moreover, the user has to define the limits of the movements for each element.

Figures 9 and 10 present two screenshots from MachineMaker.

In figure 9 the rotational tables are defined and in figure 10 the translational slides are introduced.

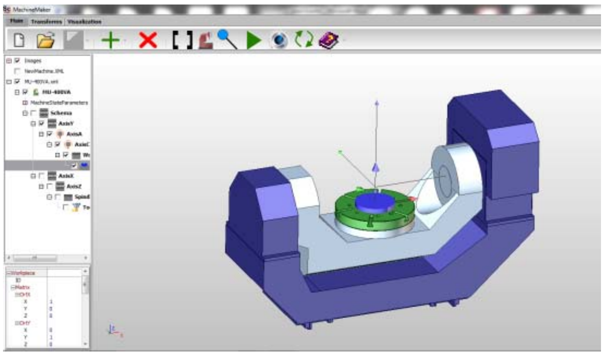

Fig. 9. Rotational tables

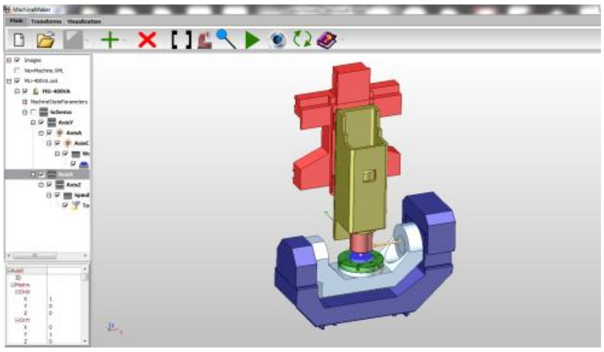

Fig. 10. Translational slides

4.1 Testing the geometric and kinematic model

After building the model, it has to be validated inside the SprutCAM main environment. For that, it had to be tested by means of simulating a complex manufacturing process.

In order to test the model, a part with a complicated shape was machined. The part was a conical gear with curvilinear teeth presented in figure 11. The generation of the shape of the teeth requires a 5D milling process.

Figures 12 and 13 shows screenshots from the simulation process unfolded in SprutCAM.

5. CONCLUSION

The competion on the international markets between manufacturers is growing each year, everyone is trying to machine parts with very high accuracy and productivity. In order to

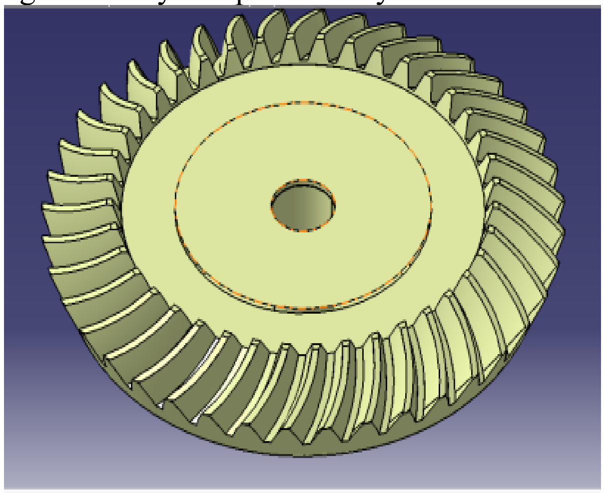

Fig. 11. The machined conical gear

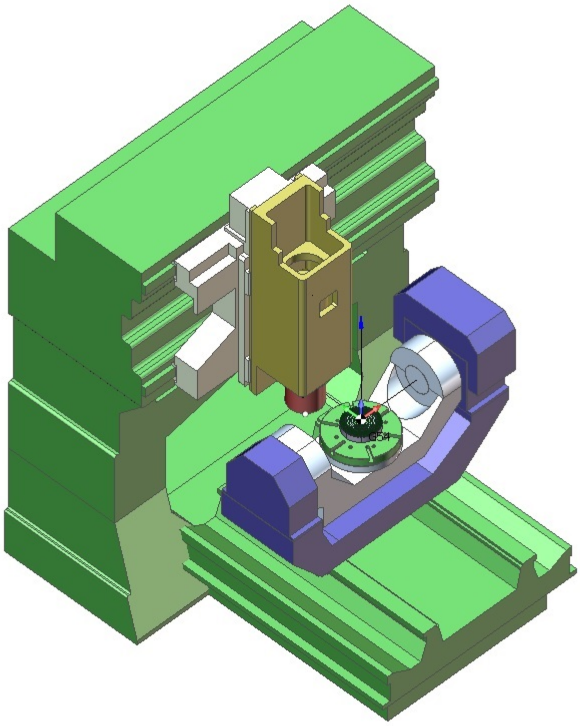

Fig.13. The simulation process (general view)

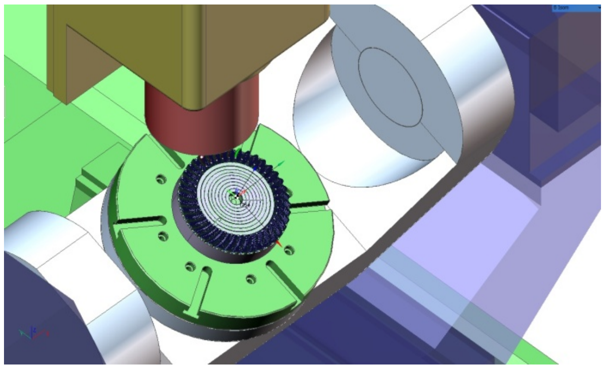

Fig. 12. The simulation process (detail)

achive these objectives, five-axis machining centers are used on a large scale, in most of the factories and wirkshops.

Five-axis machining centres are very complex and expensive CNC machine-tools. Consequentry any collisons which may occur during the machining process have to be avioded.

The most recommended approach is to use CAM software packeges which are able to perform realistic and accurate simulations of the machining process.

In order to simulate a multi-axes machining process, mainly 5D milling, a geometric and kinematic model of the CNC machine-tool is required.

Some of the CAM software packages include libraries of such models, but for the newest models of CNC machine-tool cannot be included.

Consequently, the user has to be able to build such models, using specific tools, provided with the CAM software, either as internal or external supplementary modules.

This paper presented the process of building the geometric and kinematic model of OKUMA MU-400VA five-axis machining center, using the SprutCAM software package and the MachineMaker module.

After the model was build, it was successfully tested by using it in simulating the machining process of a conical gear.

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Contribuţii privind utilizarea unei soluţii software CAM la prelucrări multi-axiale

Rezumat: Procesele de prelucrare se desfăşoară la ora actuală pe maşini-unelte cu comandă numerică, utilizând tehnici CAD/CAM. Toate pachetele software CAM de pe piaţă includ şi module specializate pentru simulare. În cazul simulării proceselor de frezare 2.5D şi 3D este necesară doar simularea mişcărilor relative dintre sculă şi piesă. Cu toate acestea, în cazul prelucrărilor multi-axiale, pentru o simulare precisă, este necesară utilizarea unui model geometric şi cinematic al maşinii-unelte. Pe baza acestui model, vor putea fi simulate şi deplasările relative dintre elementele mobile ale maşinii. Astfel, simularea va putea evidenţia atât eventualele coliziuni dintre sculă şi piesă, cât şi cele dintre elementele mobile ale maşinii. Lucrarea de faţă prezintă metodologia de construcţie a unui astfel de model geometric şi cinematic, utilizând un pachet software CAM, SprutCAM şi un modul extern al acestuia, MachineMaker.

Gabriela Alexandra MURESAN, PhD. Student, Technical University of Cluj Napoca, Department of Design Engineering and Robotics, gabby_muresan@yahoo.com, +40 264 401615

Liviu MORAR, Professor, Technical University of Cluj Napoca, Department of Design Engineering and Robotics, liviu.morar@staff.utcluj.ro, +40 264 401615

Radu-Eugen BREAZ, Professor, "Lucian Blaga" University of Sibiu, Department of Industrial Machines and Equipments, radu.breaz@ulbsibiu.ro, +40 269 21.78.71