Society of Production Engineering

**SPMS 2023**

**39. Savetovanje proizvodnog mašinstva Srbije**

**ICPES 2023**

**39th International Conference on Production Engineering of Serbia**

Faculty of Technical Sciences
University of Novi Sad

**Novi Sad, Serbia, 26. – 27. October 2023**

# AN APPROACH FOR AUTOMATIC FREE FORM SURFACE MILLING MACHINING TECHNOLOGY DESIGN

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***Abstract:*** *Parts with free form surfaces are commonly used in wide area of engineering, not only in mechanical engineering. When it comes to the area of mechanical engineering, the main problem is how to produce such parts. One of the commonly used methods is milling with ball end mill cutter on 3, 4 or 5 axis mill machines. A usual approach for production of such parts is to generate NC code in some of commercial CAM software and afterwards load it on CNC machine. In this paper is presented the software for automatic technology design which is developed at the department of production engineering of the Faculty of Mechanical engineering in Belgrade, Serbia. Based on loaded CAD models of the final product and workpiece which will be used for production software automatically gives the NC code for machining according to implemented machining strategies. The core of software is a module for machining simulation process which allow multicriteria optimization method for machining. Verification of the generated NC code was done on horizontal machining center and after that measurement of machined part where was verified quality of machined part in predefined tolerances.*

***Keywords:*** *CAD/CAM, free form surface, milling, force prediction, ball end mill cutter.*

## 1. INTRODUCTION

It is widely known that use of parts with free form surfaces is widely used in almost every field of engineering, not only in mechanical engineering. When it comes to the area of mechanical engineering, especially in area of production engineering the main challenge is how to produce such parts. The most used method for this is by machining with ball end mill cutter on 3, 4 or 5 axis CNC milling machines. For this purpose, free form surface is approximated with triangles i.e., line segments so it can be calculated surface and leading plane cross section. In the past, beside development of machining strategies it was started on research in the field of tool path optimization so that free form surface machining could be done faster, better and cheaper. The worldwide used method for toll path optimization is federate scheduling which is commonly based on specific production (MRR – **M**aterial **R**emoval **R**ate) [1, 2] or on cutting force prediction also called TWE – **T**ool

**W**orkpiece **E**ngagement [3, 4]. There are a few more methods which are also used like workpiece discretization and models with Z map for example.

In this paper is presented developed software for automatic tool part generation and optimization for milling of one parts class with free form surfaces on 3 axis milling machines with ball end mill cutter.

## 2. SYSTEM DEVELOPMENT

Research in the field of free form surface machining exist over than 20 years at the Department of Production Engineering at the University of Belgrade – Faculty of Mechanical Engineering. A few years ago, it was developed CAM software (figure 1) for automatic technology design for machining of parts with free form surfaces [5].

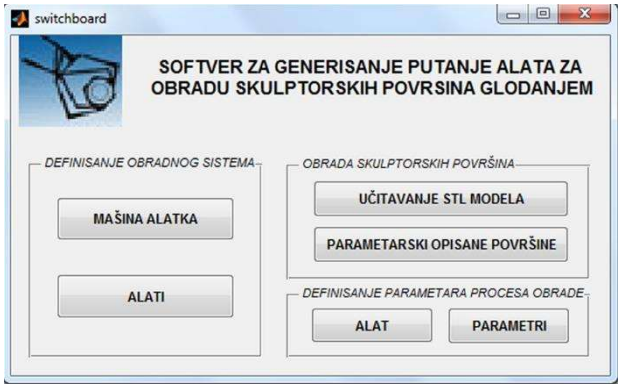


**Figure 1.** Developed CAD/CAM software [5]

The main system core is a module for cutting process simulation which allows exact calculations of machining parameters based on force prediction model [6-10] which is also developed and built in system.

Bellow, there will be given a short description of the main system components.

### 2.1 Free form surface CAD model loading

This CAM system is developed for loading CAD models from commercial CAD software which is saved in STL (Stereolithography) file format. Using of this file format allows to get approximate surface shape, figure 2 and based on that reduce the need for big numerical calculation of surface and leading plane cross section. When the CAD model is loaded, system also calculates minimal curvature radius of the surface so it can be chosen tool from the software database which is also developed and described in [5].

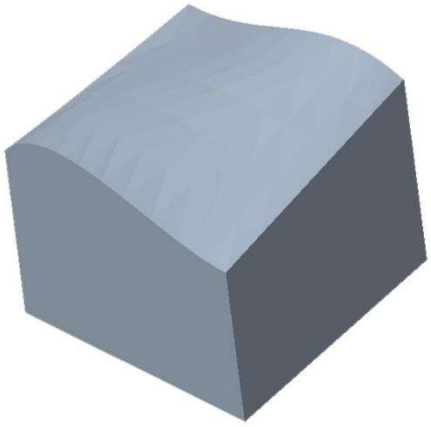

**Figure 2.** Approximated surface with triangles

In this step, software generates leading planes parallel to the coordinate axes with distances between them calculated based on demanded surface roughness defined by software used. For every leading plane it is calculated CL (Cutter Location) points which will be used to generate optimized tool path which allows machining with minimal needed time. Idea for machining strategies comes from detailed analysis of commercial CAM softwares which are described in [11-13]. For further procedures in this stage workpiece CAD model is also loaded in the same format as part which should be machined.

### 2.2 Cutting process simulations

After CAD model is loaded and appropriate tool is chosen, system calculate number of tool revolution and federate from [14, 15]. This federate is corrected by amount of material in every CL point so total cutting force will be the same value in every CL point. On this way, it is avoided tool breakage because for every tool loaded in software database is given the maximal value of allowed cutting force. Developed system has possibility for upgrade with new materials and tools because parameters for force model prediction are in direct correlation with chosen tool and workpiece geometry and material. Described

procedure allows rough machining with an approximate shape of surface directly in one pass from workpiece without previous pre-machining. If the direct machining with ball end mill cutter isn't possible, system gives massage that pre-machining method is needed. In those cases, it is possible to get the NC code for rough machining with end mill or milling head described in [16, 17].

### 2.3 Tool path generation

After the CL points and machining parameters are calculated system chooses which of the implemented machining strategies gives minimal machining time. For now, system has 3 solutions for tool part: parallel, spiral and ZIG-ZAG topology. Generation of the NC code is automated and it is after calculation stored in installation folder of CAM software.

## 3. EXPERIMENTAL VERIFICATION

### 3.1 NC code generation

With the developed application is allowed automated tool path generation, figure 3.

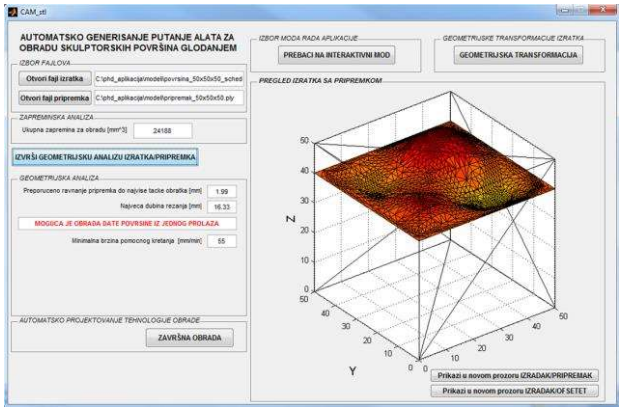


**Figure 3.** Developed CAD/CAM software [5]

It is not needed expert knowledge from user to work with software. At the beginning of technology design, user loaded CAD models of part and workpiece. After that it is needed to input required surface roughness and tolerance. Tool selection is automated by the geometry analysis of the loaded part, but it is also possible to manually choose tool for machining. User can also choose a machining strategy if there is some special demand.

The final output from generated CAM software is NC code. That code is generated by multicriteria optimization and allows machining of loaded part in one pass with ball end mill cutter. For this purpose, all the machining parameters and tool part topology are generated in automatic software mode.

### 3.2 Machining

Automatically generated NC code is used for machining. Machining was performed on Horizontal working center ILR HMC500/40 at the University of Belgrade – Faculty of Mechanical Engineering, Department of Production Engineering.

Workpiece from aluminum AlMg4.5Mn was fastened on machine table with dynamometer, figure 4. Machining was done with ball end mill cutter without cooling because we wanted to tested generated force prediction model which doesn't predict the use of a cooling system, figure 4.

**Figure 4.** Machining on ILR HMC 500/40 [5]

## 4. CONCLUSION

By the described procedures in this paper it was presented one way for free form surface machining, especially NC technology design for this purposes. Use of the given procedures are justified only in rough machining where depth of cut is large and it is not needed to get exact shape of the surface, which will be conducted in finish machining where depth of cut is small.

**ACKNOWLEDGEMENT**

The author wishes to thank the Ministry of Science, Technological Development and Innovation of Republic of Serbia for providing financial support that made this work possible (by the contract: 451-03-47/2023-01/ 200105 from 03.02.2023).

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