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SOFTWARE UPGRADE FOR AUTOMATIC ROUGH MILLING TECHNOLOGY DESIGN FOR PARTS WITH FREE FORM SURFACES

Goran MLADENOVIC[1,*], Ljubodrag TANOVIC[1], Radovan PUZOVIC[1], Mihajlo POPOVIC[1], Milos PJEVIC[1]
[1]University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia
*gmladenovic@mas.bg.ac.rs

Abstract: *Use of free form surfaces is present in almost all area of everyday living. In mechanical engineering such products are usually called parts with free form surfaces. Today is very easy to design such parts using some of commercial CAD software package. Unlike designing, production of those parts are more difficult. There are many strategies to machine parts with free form surfaces. The most used is milling method with ball mill cutter. In previous, at the Department for Production Engineering at the Faculty of Mechanical Engineering at Belgrade many research were conducted in the field of free form surface milling. Recently, the software for automatic technology design for parts with free form surfaces was developed. In this paper is presented developed procedure for software upgrade with new procedure for rough machining with milling head and ball end mill cutter.*

Keywords: *CAD/CAM systems, Computer Graphic, Free form surfaces, Ball end mill cutter, Milling.*

1. INTRODUCTION

In almost all commercial CAD software, free form surfaces are usually described in parametric form using parametric equations [1]. Parametric form allows tool path generation in an easy way to calculate CL (Cutter Locations) points across all surface which should be machined. Tool path generation include two segments and it is [2]:

- Tool path topology,
- Tool path parameters.

Generally, the milling with ball end mill cutter is the most used in machining of free form surfaces on 3, 4 and 5 axes milling machines. Machining with ball end mill include surface approximation with line segments. Until today three machining methods are developed, iso-parametric, iso-planar and iso-scallop machining method. Many years ago it was started research in the field of tool path optimization. One of the common use is federate scheduling optimization method. It can be based on specific production (MRR – **M**aterial **R**emoval **R**ate) [3, 4]. Second optimization method is based on cutting force prediction also called TWE – **T**ool **W**orkpiece **E**ngagement [5, 6]. It is also used models with Z map, workpiece discretization and similar.

In this paper is presented procedure and software upgrade for automatic technology design for free form surface machining, previously developed at the Faculty of Mechanical Engineering in Belgrade.

2. DEVELOPED SOFTWARE

In previous research CAD/CAM software for automatic technology design for free form surface machining is developed [7]. Software allows work with CAD model of free form surface in STL file format, figure 1.

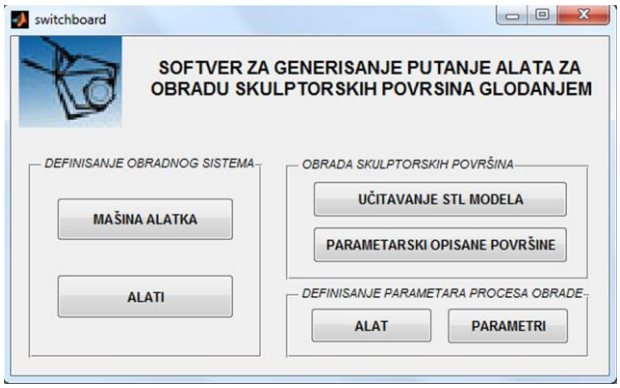


Figure 1. Developed CAD/CAM software [7]

After loading of CAD part file, it is possible to obtain NC code for machining with ball end mill cutter with multi criteria optimization method described in [8-10].

In cases when it is not possible to obtain NC code for machining with ball end mill cutter it was developed procedure for pre-machining with end mill cutter descripted in [11-14].

Tool path parameters (number of tool revolution and feedrate) are calculated from literature based on recommended values from [15, 16]. It is also possible to calculate cutting force so it can be machined with chosen machine.

Previous descripted procedure is presented on figure 2 [16].

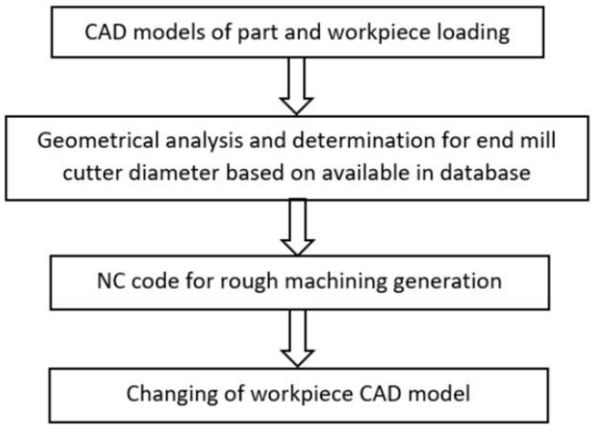


Figure 2. Developed CAD/CAM software [16]

Developed machining procedure is allowed by formed tool database which is included in system, figure 3. Entering this form is allowed from button “ALAT” from on figure 1.

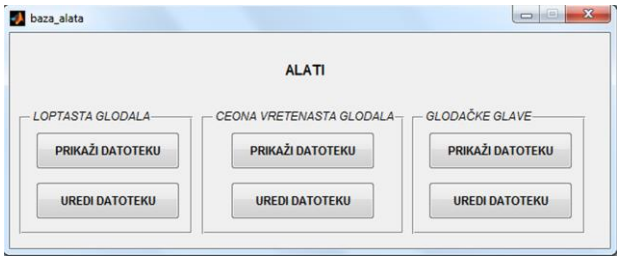


Figure 3. Form for toll database entering [7]

Using generated NC code for rough machining with ball end mill it is possible to get approximate shape of the surface (figure 4) which should be machined with ball end mill cutter which is also allowed with developed system.

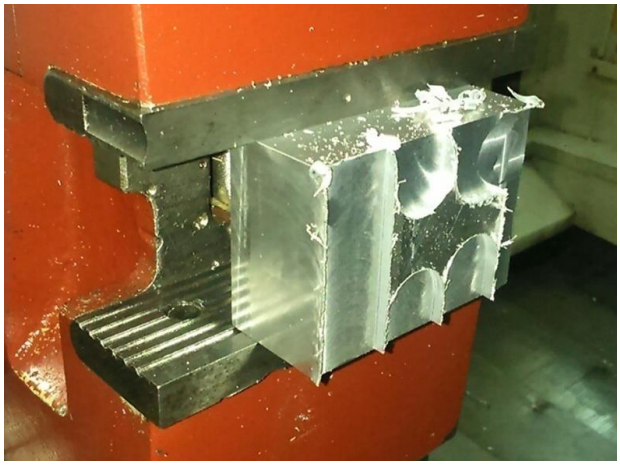


Figure 4. Workpiece after rough machining [7]

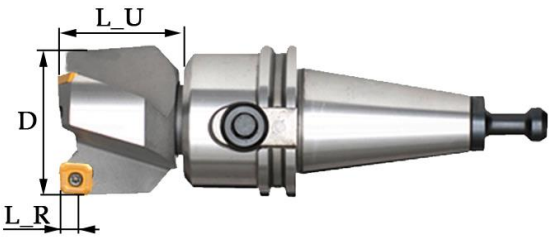
3. SOFTWARE UPGRADE

The next step in software development was to extend tool database with milling head and implement new procedure for rough pre-machining with milling head.

Usage of this machining procedure is justified in cases where is needed to cut as much as possible material in short time of period in order to minimize machining time and according to that final product price.

Generally speaking, description of milling head is similar to end mill cutter, but in developed system it is used few attributes to describe this kind of tool: Tool ID (ID), Tool

Diameter (D), Length of the cutting edge (*L_R*), Total Length (*L_U*), Number of teeth (z), Tool material (mat), Length correction mark (H). All described atributes are showen on figure 5.



ID	D	L_R	L_U	z	mat	H

Figure 5. Milling head file [7]

Current database is extended on this way to allow software to automatically chose machining with this tool in cases where that is possible.

In this state, software allows input of three types of tools and it is also possible to update database with new tools and eventually erasing some of existing in database according to procedure showed on picture 6.

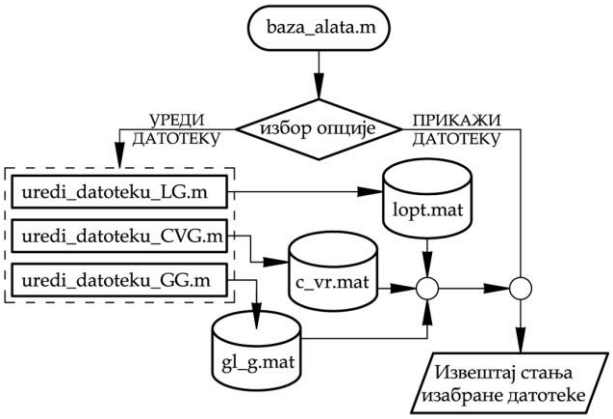


Figure 6. Tool database upgrade procedure [7]

Also, in any time it is possible to get current state of tool database with button "PRIKAZI DATOTEKU" from figure 3.

In cases where software recognize that it is possible to cut extra workpiece material with milling head it is allowed to input stock allow value for finish machining (δ_{GG}), figure 7. This stock allow will be machined in next machining step with ball end mill cutter in one or few passes depending on conducted geometrical analysis which is descripted in [7]. If software user don't want to machine with stock allow it is possible to input value equal to 0.

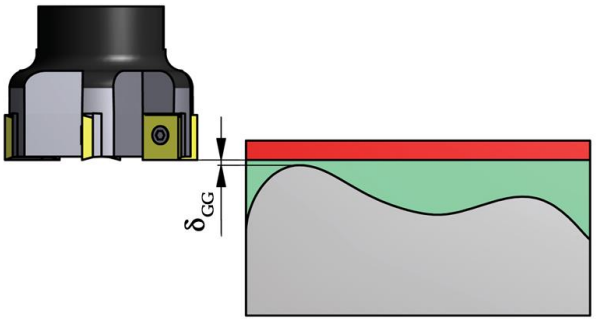


Figure 7. Stoch allow definition [7]

4. EXPERIMENTAL VERIFICATION

Using developed software, it was generated NC code for rough and finish machining of part with free form surface previously designed in commercial CAD software and saved in STL file format, figure 8.

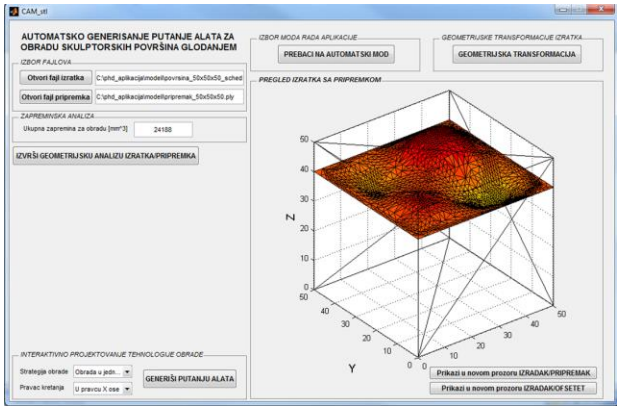


Figure 8. Stoch allow definition [7]

After machining on ILR HMC 500 working cente, measuring of part was conducted and point cloud was generated. Using Matlab software map of deviation was generated based on CAD model and generated point cloud, figure 9.

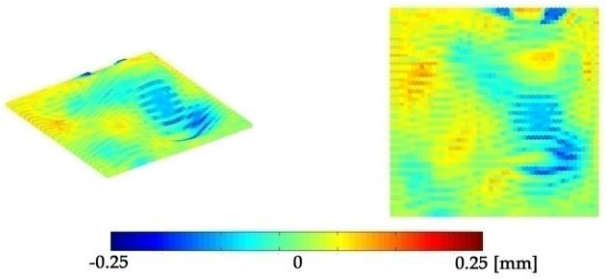


Figure 9. Map of deviation [7]

Based on analysis it was concluded that machining was performed in defined tolerances and surface roughness.

5. CONCLUSION

In this paper is descripted developed procedure for rough machining with milling head and its implementation in previously developed software. It was experimentally verified usage of developed software based on conducted machining and analysis from generated map of deviation.

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REFERENCES

[1] Li C.L., A geometric approach to boundary-conformed toolpath generation, 2007. Computer Aided Design, 39(11), pp. 941-952.

[2] Choi B.K., Jerard R.B., Sculptured surface machining - theory and applications, Kluwer Academic Publishers, Dordrecht, 1998.

[3] Ip R.W.L., Lau H.C.W., Chan F.T.S., An economical sculptured surface machining approach using fuzzy models and ball-nosed cutters. Journal of Materials Processing Technology, 138(1-3), pp. 579-585, 2003.

[4] Li Z.Z., Zheng M., Zheng L., Wu Z.J., Liu D.C., A solid model-based milling process simulation and optimization system integrated with CAD/CAM. Journal of Materials Processing Technology, 138(1-3), pp. 513-517, 2003.

[5] Altintas Y., Manufacturing Automation – Metal Cutting Mechanics, Machine Tool Vibrations and CNC Design, Cambridge University Press, Cambridge, 2000.

[6] Layegh S.E.K., Lazoglu I., Offline Force Control and Feedrate Scheduling for Complex Free Form Surfaces in 5-Axis Milling. Procedia CIRP, Fifth CIRP Conference on High Performance Cutting 2012, 1, pp. 96-101, 2012.

[7] Mladenovic G. Tool Path Optimization in Sculptured Surface machining, Doctoral Disertation, University of Belgrade – Faculty of Mechanical Engineering, 2015. (in Serbian).

[8] Mladenovic G., Tanovic LJ., Ehmann K.F.: Tool Path Generation for Milling of Free Form Surfaces with Feedrate Scheduling. FME Transactions, 43(1): pp. 9-15, 2015.

[9] Mladenović G., Tanović Lj., Puzović R., Pjević M., Popović M.: The Development of Software Solution for Automatic Choise of Machining Parameters for Free Form Surfaces Parts, 41th JUPITER Conference, pp. 2.19-2.24, Belgrade, June, 2018. (in Serbian).

[10] Goran M. Mladenovic, Marko J. Milovanovic, Ljubodrag M. Tanovic, Radovan M. Puzovic, Milos D. Pjevic, Mihajlo D. Popovic, Slavenko M. Stojadinovic: Development of Application Software for Automatic Manufacturing Techology Design of Free Form Surfaces, International Conference of Experimental and Numerical Investigations and New Technologies - CNN TECH 2019, str. 65-65, Zlatibor, June, 2019.

[11] Goran M. Mladenovic, Marko J. Milovanovic, Ljubodrag M. Tanovic, Radovan M. Puzovic, Milos D. Pjevic, Mihajlo D. Popovic: Concept Development for Rough Milling of Free Form Surfaces, International Conference of Experimental and Numerical Investigations and New Technologies - CNN TECH 2020, str. 45-45, Zlatibor, June, 2020.

[12] Mladenović, G., Tanović, Lj., Milovanović, M., Popović, M., Puzović, R., Pjević, M., Development of a System for Automatic Technology Design for Pre-Machining of Parts with Free Form Surfaces, 42th JUPITER Conference, pp.2.1-2.6, Belgrade, October, 2020. (in Serbian).

[13] Goran M. Mladenovic, Ljubodrag M. Tanovic, Radovan M. Puzovic, Milos D. Pjevic, Mihajlo D. Popovic, Ivana Jevtic, Rough Milling with End Mill Cutter in Apllication for Free Form Surfaces Machining, International Conference of Experimental and Numerical Investigations and New Technologies - CNN TECH 2021, pp. 54-54, Zlatibor, June/July, 2021.

[14] Kalajdzic, M. et al. Cutting technology - a handbook, FME, Belgrade, 2017 (in Serbian).

[15] Kalajdzic, M. Manufacturing technology, FME, Belgrade, 2019 (in Serbian)

[16] Goran Mladenović, Ljubodrag Tanović, Radovan Puzović, Marko Milovanović, Mihajlo Popović, Miloš Pjević, Vojislav Simonović, Development OF CAM System for Rough Machining in Free Form Surface Manufacturing, 5th International Scientific Conference COMETa2020, pp. 84-90, Jahorina, B&H, November 2020.