COMETa 2020
5th INTERNATIONAL SCIENTIFIC CONFERENCE
26th - 28th November 2020
Jahorina, Republic of Srpska, B&H
University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

DEVELOPMENT OF CAM SYSTEM FOR ROUGH MACHINING IN FREE FORM SURFACE MANUFACTURING

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Abstract: Many areas of engineering today make use of parts obtained via free form surface machining. Production of these parts usually involves milling with ball end mill cutter. Often however it is not possible to perform the machining in one pass only and therefore it becomes necessary to perform rough machining first. This paper describes the developed procedure and the system for automatic tool path generation for rough milling.

Key words: CAM System, Free Form Surfaces, Manufacturing, Rough Machining

1 INTRODUCTION

Parts with free form machining are present in every day life and their use even rises exponentially [1]. These parts are used in many different fields of engineering, but particularly in Mechanical Engineering where their production is of main concern. Machining is usually performed by milling with ball end mill on a 3 or 5-axis CNC machine tool [2]. The main disadvantage in most commercial CAM software is that it is not possible to predict cutting conditions and cutting force to avoid tool damage [3]. In recent years, research in the field of multi-criteria tool path optimization is ever increasing [4].

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Based on previous research in the field of free form surface machining conducted at the Faculty of Mechanical Engineering in Belgrade, Serbia it was recently continued to particularly envelop rough milling with end mill cutter [5 - 7].

This paper describes the developed procedure as well as the system for automatic toll path generation for rough milling with end mill cutter. The developed system is implemented in a software solution which represents a CAD/CAM application for tool path generation and optimization. An experimental verification description of the developed system on CNC working center ILR HBG 500/40 is also given.

2 PROBLEM DEFINTION

Sometimes, it was not possible in the previously developed system to obtain the NC code for some CAD models because an oversized depth of cut was present. In certain cases, it was necessary to develop procedures for rough machining in order to get the work piece stair-like (Figure 1) which would allow further/finial machining with ball end cutter. Rough machining will be performed with an end mill cutter where the tool diameter will be automatically determined based on the CAD model geometry and available tools in the database for used machine tool.

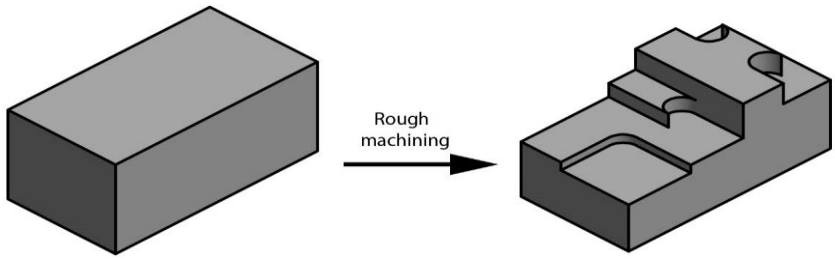

Figure 1. *Work piece before and after rough machining with an end mill cutter*

3 SYSTEM CONCEPT

The developed system should generate the NC code for rough machining with an end mill cutter according to the procedure given on Figure 2.

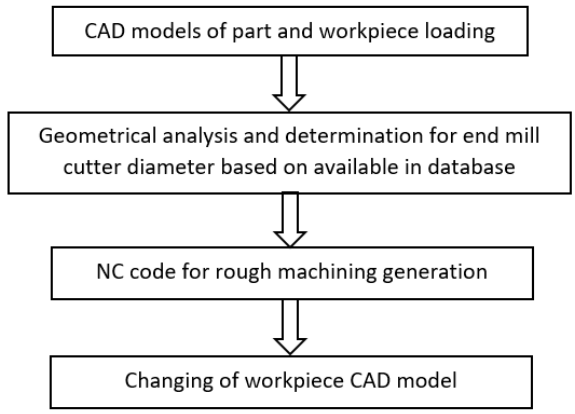

Figure 2. *Procedure for rough machining with an end mill cutter*

The developed system supports loading of workpiece and part CAD models in STL file format. After loading these files, the system performs geometrical analysis in order to determine the possibility of machining the part in one pass with a ball end mill cutter. If not possible, the system activates the module for rough machining. In that case rough machining will be performed with an end mill cutter. For this purpose, a new procedure was developed for automatic NC code generation. The complete procedure is given/explained in the following steps/subsections.

3.1 Available tools database generation

This step is used primarily because all machines have some tools in their tool magazine. Therefore, the system user should update the database with available tools before machining. The attributes used for describing the end mill cutter are:

- Tool ID
- Tool diameter
- Length of the cutting edge
- Length to tool shoulder
- Number of teeth
- Helix angle
- Tool material
- Length correction mark

The most important attribute for automatic tool determination is the tool diameter since it should be equal or less than as calculated from the previous geometrical analysis.

3.2 Axial and radial stock allow input

This step provides enough material for the next machining step, which is usually the final machining with a ball end mill cutter. Based on the machining method with an end mill cutter two types of stock allow must be defined (in millimeters). Radial (δ_{rad}) which is parallel to the tool axis and axial (δ_{ax}) which is perpendicular to the tool axis. This step is usually common for all commercial CAM software. This system also supports zero input value, just as in the commercial software.

3.3 Cutting parameters calculation

When the tool diameter is specified it is possible to calculate machining parameters based on conducted geometrical analysis. The machining parameters are calculated based on the recommended values from [8, 9] according to the role for the CNC machine tools. The number of tool revolutions is calculated from the recommended cutting speed (V) for used tool/work piece material as:

$$n = \frac{1000 \cdot V}{\pi \cdot D} \quad [rpm] \tag{1}$$

Feedrate is calculated according to the previous calculated number of revolutions, recommended step (s_z) and number of teeth (z) for used end mill cuter as:

$$V_s = n \cdot s_z \cdot z \quad [mm/min] \tag{2}$$

Naturally, calculated machining parameters will be tested and verified against the available machine power. The system user must provide input of the available power for used machine tools before starting the system. Required cutting power is determined based on cutting depth (a), cutting width (b) and previously calculated feedrate as:

$$P = \frac{a \cdot b \cdot V_s}{1000} \cdot 0.064\ [kW] \tag{3}$$

If available machine power does not suffice cutting conditions, the system performs a reduction of machining parameters to obtain machining conditions according to available machine power.

3.4 Tool path generation

The final step for NC code generation is to generate the tool path. The tool path is determined by the rule that tool should go to trajectories parallel to the coordinate planes, as described in Figure 3.

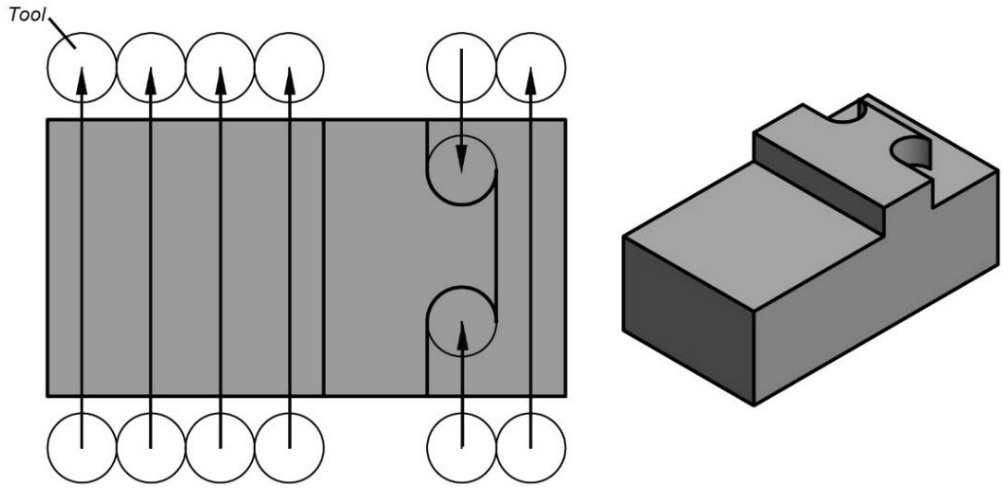

Figure 3. *Tool path generation*

The plane to be used depends on the volume of possible material removing and machining time. The system seeks for a tool path that will generate machining with minimum machining time and maximum material volume removal.

4 SOFTWARE DEVELOPMENT

Using the MATLAB software package, the previously generated CAD/CAM application was upgraded (Figure 4). This application allows the user to automatically generate a tool path with minimal working knowledge using this type of software. The software application supports generation of the NC code for final free form surface machining with a ball end mill cutter and also for rough milling with an end mill cutter. If needed, user has the freedom of also manually generating the tool path and cutting parameters.

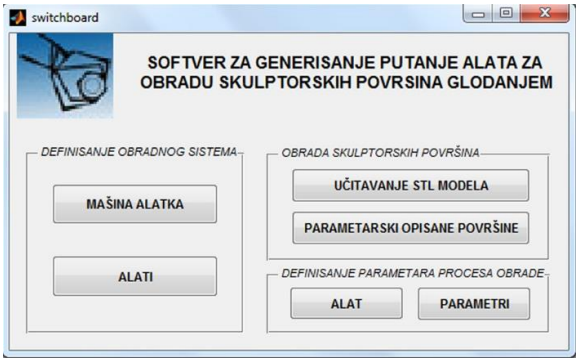

Figure 4. *Developed software [6]*

5 EXPERIMENTAL VERIFICATION

In order to validate the use of developed application an experimental verification was conducted. A CAD model generated in commercial CAD software was used and saved as an STL file. Also workpiece CAD model was generated and saved as STL file.

After loading the above mentioned files in the developed application a message appeared that machining in one pass with a ball end mill cutter is not possible. An automatically generated solution was proposed for rough milling with an end mill cutter available in the database for given machine tool, in this particular case with a diameter of 20 mm. After accepting the proposal, the NC code for machining was generated.

The work piece was tightened in the machine clamp based on work table on the CNC working center ILR HMC 500/40 (Figure 5).

Figure 5*. Machining on CNC working center [6]*

After machining, the measurement of the produced part was conducted on the CMM and measured data was saved as point cloud. A map of deviations was then generated from the point cloud which allowed concluding that the machining was performed within defined limits and tolerances.

6 CONCLUSION

Based on the described procedure and verification, a conclusion can be made that the developed system represents a modern CAM application for automatic tool path generation. The developed software application provides even non-experienced users a possibility to work in the field of free form surface machining.

Experimental verification shows that the machining with the generated NC code was suitable for rough machining with an end mill cutter which allowing further/final machining with a ball end mill cutter.

The work on further development of new procedures and their implementation in the currently developed system will naturally continue with fresh new ideas for improvement.

ACKNOWLEDGMENT

The author wishes to thank the Ministry of Education, Science and Technological Development of Serbia for providing financial support that made this work possible (by the contract: 451-03-68/2020-14/200105).

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