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Research Article

ASSESSMENT OF SURFACE QUALITY FOR CHOSEN MILLING STRATEGIES WHEN PRODUCING RELIEF SURFACES

Jan Varga[1], Jozef Stahovec[1], Jozef Beno[1], Marek Vrabel'[1]

[1] Department of Technologies and Materials, Faculty of Engineering, Technical University in Košice, Mäsiarska 74, 040 01 Košice, Slovak Republic, e-mail: jan.varga@tuke.sk; jozef.stahovec@tuke.sk; jozef.beno@tuke.sk; marek.vrabel@tuke.sk

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ABSTRACT
The paper deals with design and modeling of the relief surfaces that are produced in milling. Modeled and real surface quality is presented for the chosen fragments of the relief surfaces. Fragmentation of the relief surfaces has been made by the surface sampling. Milling strategies are compared with regard to surface formation. Surface quality was checked with regard to applied cutting conditions.

Keywords: relief surface, fragmentation of the surface, milling strategies.

INTRODUCTION

The subject of this paper is the design and manufacturing of parts with complex shaped surfaces. Relief surface is widely used in the design of complex product with molds and dies features. These surfaces are often produced by 3 and 5-axis computer numerical control machine tools using ball-end milling cutter. Mansour [1] deal with automatically generate part programs for machining sculptured surfaces by using CAD/CAM packages. For milling relief surface it used the ball milling. Siller [2] predicts the cycle time of high-speed milling for sculptured surfaces with high feed rates. The experiments and predictions were focused on representative surfaces of dies and molds, whose geometric complexity and complexity distribution were, modified parametrically (a set of representative sculptured surfaces with spherical caps and a forging die surface). The prediction of cycle time under high feed rate cutting conditions studied by Monreal [3] and Kim [4] for CNC programs of roughing operations with a relatively large proportion of long tool paths and zigzag patterns. In these studies, the proposed methods for cycle time prediction are based on characterization of machine tool acceleration and principles of constant acceleration motion. Feng [5] presents a new approach for the determination of efficient tool paths in the machining of sculptured surfaces using 3-axis ball-end milling. The objective is to keep the scallop height constant across the machined surface such that redundant tool paths are minimized. The effectiveness of the present approach is demonstrated through the machining of a typical sculptured surface. The surface texture depends on the optimal set of parameters, so it is needed for the circumspect design of the process [6].

EXPERIMENTAL DETAILS

Milling tests were performed on 3 axes CNC milling machine tool Emco Mill 155 equipped with digital control system Heidenhain TNC 426. Milling experiments were conducted by using cutting coolant. In the experiments end mill and ball nose solid carbide cutting tools were used. Cutting tools parameters and cutting conditions are shown in Table 1. Cutting conditions were chosen based on the recommendations of the tools manufacturer and the possibilities of the machine. Aluminum alloy with dimensions 145×140×30 mm was used as a workpiece material. 3D model of part was designed in CAD software Solid Works

2012 and CAM software SolidCAM was usedto manufacture this part . Part model and machined part is shown in Figure 1.

Fig. 1. Part model and final part

SOLID MODEL WITH RELIEF SURFACE

There are 5 types of representation of complex surfaces in CAD systems. Different types of these representations are shown in Figure 2.

Analytical representation

The basic advantage of analytical representation is its accuracy. Descriptions of the objects represented using spline frontier model consist of points, curves and spline surfaces. Such models contain full information to describe the model. This model representation is used for very precise geometric modeling in CAD/CAM systems.

Wireframe model

Wireframe model consists of points, which are connected to curves. In this case two points are connected with line. The model created in this representation has many limitations and disadvantages, because there are missing data about the volume between lines.

Planar model

This kind of model works with surfaces in three-dimensional Cartesian coordinate system. They are used in the areas of aerospace, shipbuilding and automotive industries, where the processing of complex surfaces placed great demands. The procedure consists in creating of vertices, edges, and finally defines the area [7].

Volume model

Model is defined by their borders (e.g. walls, edges, lines, curves and points).

Voxel model

Voxel models are similar to bitmap graphics. When this model is used, the object is decomposed into elementary volume units – cubes. The basic unit of description is a Voxel, which is a volume unit representing the value of the cell in three-dimensional Cartesian coordinate system.

SURFACE QUALITY AND USED MILLING STRATEGY

By the sequence operations of technological process framework more machining strategies were designed, which divides each operation into multiple sections. Using multiple strategies it is possible to precisely control of tool paths when machining complex surfaces, that model includes.

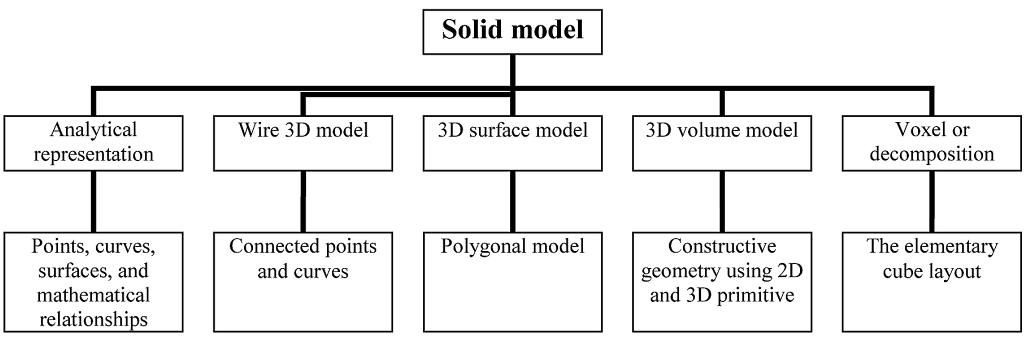

Fig. 2. Representation of solid model

Roughing milling operation was divided into two stages, basic shape roughing and roughing pockets respectively. 3D Milling strategy was used in roughing operation and end mill with a diameter 12 mm was employed in machining. Corresponding cutting conditions are shown in Table. 1 Depth of cut a_p was set at 1–3 mm and width of cut a_e was set to 4.8 mm. Start-up angle of the tool into the material was 5°. Individual tool paths after roughing and machined surface after this operation are shown in Figure 3 [8].

Semi-finishing operation was divided into milling residual material from previous operations and milling head contour parts. 3D milling and contouring strategy was chosen. In this operation end mill with diameter 6 mm was used. The depth of cut a_p was in range 1–2 mm and the width of cut a_e was set to 1 mm. Tool paths after semi-finishing shows Figure 4 and machined surface after the semi-finishing operation are shown in Figure 4. By finishing external surface was used ball nose mill, diameter Ø 8 mm. Was used HSS strategy-morph between two boundary curves, i.e. strategy between the two guide curves. Tool paths after finishing external surface and real manufactured part are shown in Figure 5.

Finishing operation of the internal surfaces, which was divided into 19 sections, as this is the completion of functional bearing surfaces. Were used HSS-morph between two boundary curves (between the two guide curves), HSS Parallel to curves (parallel under the curve) and 3D Milling strategy. Was used ball nose mill, diameter 2 mm. Tool paths in finishing the internal surfaces Figure 6 shows and the subsequently surface after the operation shows Figure 6. The largest share of time had operations in which ball nose mill, diameter 2 mm was used [8].

Table 1. Tool parameters and cutting conditions for milling

Tool	Diameter D [mm]	Number of flutes	Feed XY [mm/min]	Feed Z [mm/min]	Spin rate S [RPM]	Depth of cut a_p [mm]	Width of cut a_e [mm]
End mill	6	2	200	70	5000	1–2	1
End mill	12	2	400–485	150	3750–5000	1–3	4,8
Ball nose mill	2	2	60	20	5000	0,3–0,75	0,2–0,8
Ball nose mill	4	2	120	40	5000	0,5	1,2
Ball nose mill	8	2	250	80	5000	0,5	0,4

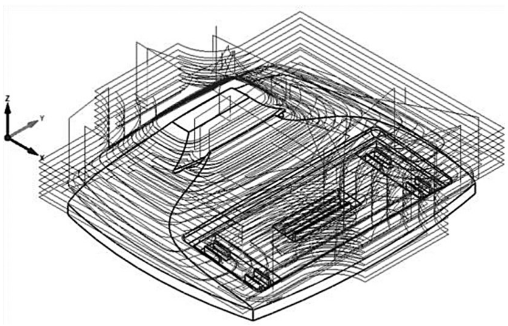


Fig. 3. Roughing

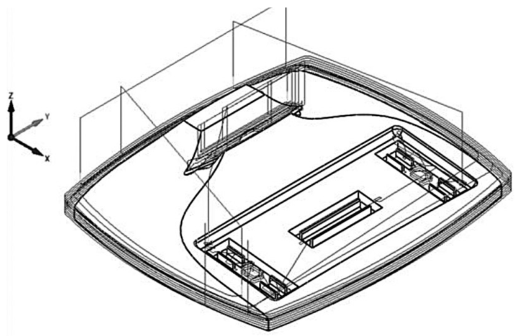
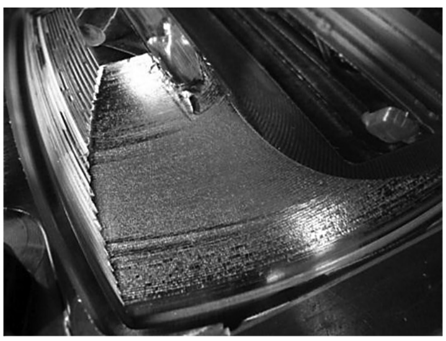

Fig. 4. Semi-finishing

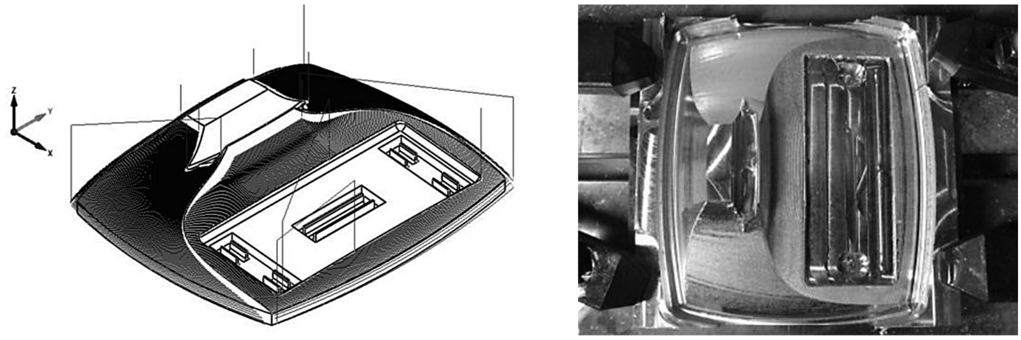

Fig. 5. Finishing external surface

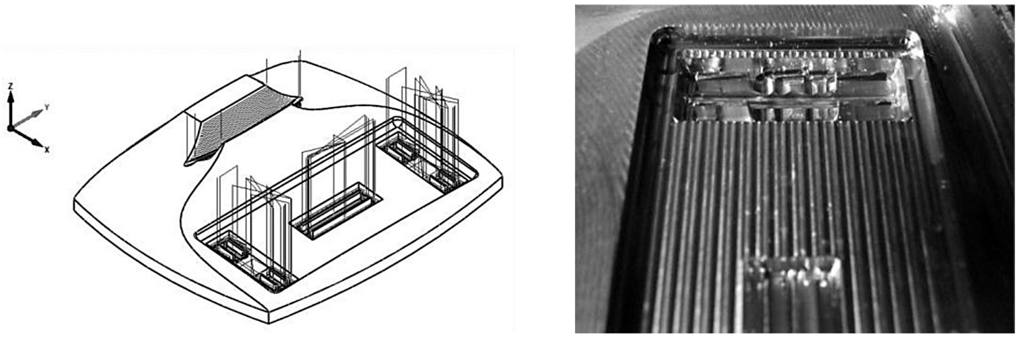

Fig. 6. Finishing internal surface

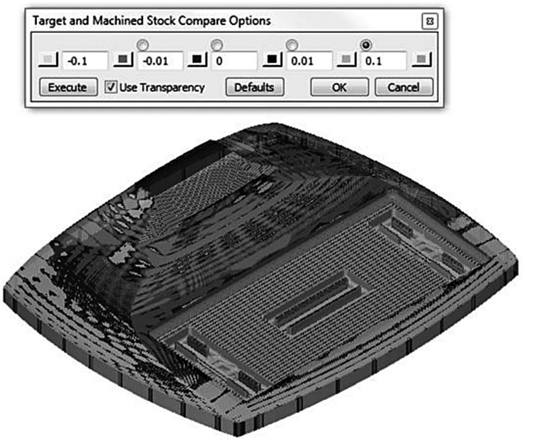

Fig. 7. Target and machined stock compare options

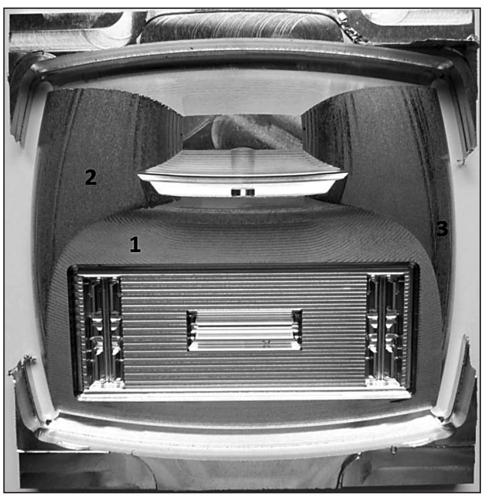

Fig. 8. Fragmentation relief surface

The estimated time of proposed operations was 8 h 10 min and the resulting quality of machined relief surface shown in Figure 7. Estimated deviation of machined surfaces has been –0.01 mm and in some places up to –0.1 mm. CAM system offers possibility to compare deviations between target and machined model and proof achieved surface quality after machining.

FRAGMENTATION OF THE RELIEF SURFACE

The tool marks are clearly visible in Figure 8 and fragments with sampling are shown in Figure 9. Ball nose mill creates on machined surface peaks and valleys – scallop height *Rz*. Acceptable surface roughness value *Rz* for that particular part was set to 5 μm. Figure 9 illustrates different chosen fragments of parts on machined surface. The machined relief surfaces were finished by grinding and hand polishing.

CONCLUSION

The presented study was performed concerning the relief surface and its aim was to determine

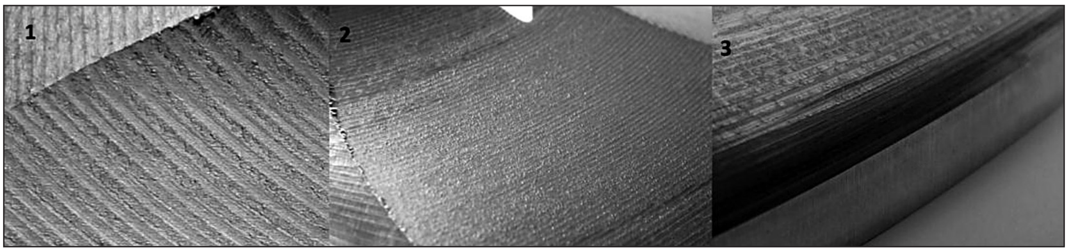

Fig. 9. Fragment with sampling

appropriate procedure to select tool path strategy when machining parts consisting of relief surfaces. The resulting procedure was chosen from several alternatives while the criterion of selecting was the resultant surface quality, production time and milling strategies, as well. Such a sort of analysis was performed as a proper use of the available CAM system. Machined surface of the workpiece produced bears characteristic marks of the ball nose milling cutters. Their locations and height of the resultant cusps were changed according to the inclination of the tested fragment area. Surface quality was checked according to the applied cutting conditions. Generally, the areas with highest inclination of the surface fragments was found out to achieve desired scallop height, therefore, these areas require a smaller amount to apply hand finishing operations.

Acknowledgements

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