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ASPECTS REGARDING THE OPTIMUM CUTTING TOOL PATH IN PROCESSING FREE-FORM

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Rezumat. *Această lucrare tratează optimizarea traseelor sculelor așchietoare în cadrul programelor de tip CAM, pentru cazul prelucrării suprafețelor complexe pe mașini-unelte cu comandă numerică. În vederea realizării dezideratului se propune o metodologie care abordează problema prelucrărilor mecanice în 3 axe cu o freză cilindro-frontală tip "ball nose" de diametru mic, ce urmărește profilul unei suprafețe complexe. Sunt considerate două cazuri, în ambele cazuri utilizându-se o freză cilindro-frontală de tip "ball nose": un traseu al sculei cu o deschidere unghiulară mai mică de 30° și al doilea caz, în care traseul sculei așchietoare este mai mare de 30°. Obiectivul principal este de a determina care este unghiul optim pentru a realiza o suprafață cu o rugozitate mai bună, un timp mai scurt in procesul de așchiere și totodată o durabilitate a sculei așchietoare mai mare, ținând cont și de ceilalți factori care apar în procesul de prelucrare. Acest lucru se va face prin indicarea și editarea traseului de sculă în așa fel încât scula să nu aibă mai multe intrări și ieșiri de pe suprafața piesei, ceea ce poate duce la scăderea timpului de lucru cu până la 10%.*

Abstract. *This paper describes an approach on tool paths optimization in CAM-type software for milling free forms, with the goal to improve efficiency in processing using CNC machine tools. The methodology proposed in this paper, tackles the problem of mechanical processing in 3 axes using ball nose milling cutters of small diameters, which follows a freeform profile. I will consider two cases: the first one considers the ball nose end mill route on a free form with an angle of less than 30°, the second one with a tool path greater than 30°. The main objective of this paper is to determine the optimum angle in order to obtain a better surface roughness, a shorter time of processing and also a higher tool-life, all these by considering all other factors that occurs in the manufacturing process. This will be done by indicating and editing the tool path so that the tools will the minimum entries and exits on the surface of the piece. This will lead to a 10% decrease of the working time.*

Keywords: CAM, tool path, free form, optimization

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Introduction

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The milling process requires a milling machine, workpiece, fixture and cutter. By feeding the workpiece into the rotating cutter, material is cut away from this workpiece in the form of small chips to create the desired shape. Milling is typically used to produce parts that are not axially symmetric and have many features, such as holes, slots, pockets, and even three dimensional surface contours. Parts that are fabricated completely through milling often include components that are used in limited quantities, perhaps for prototypes, such as custom designed fasteners or brackets. Another application of milling is the fabrication of tooling for other processes. For example, three-dimensional molds are typically milled. Milling is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been formed. Milling is a process of removing extra material volume by moving the tool cutting edge relative to the workpiece surface. Today this process is controlled by implementing CAD / CAM software in order to make the tool path, and finally the NC code.

Current methods of processing free form surfaces involves important decisions made by user regarding tracking the workpiece surface profile by modifying and editing the tool path. All these decisions are important for determining the accurate interval successions of the routes that are to be executed by the tool and to find the optimal tool path to process the workpiece surface [3]. We will adopt a new approach using CAM software on a free form segment where the edit tool paths in an optimal way in which the tool will follow the profile of the piece, in order to minimize the lead in and lead out points. Using this method will obtain a better surface roughness, a lower processing time and a longer usage of the tool.

Free form surfaces are often found in manufacturing of plastic injection molds, aluminum molding and in aerospace industry. Even with a complex CAM software which defines the direction of the tool path, machining strategy has a major role in the entire manufacturing process. Choosing and defining processing strategy involves finding the optimal parameters which often require a series of operation in free form areas with difficult access.

Free forms milling methodology consists in roughing, semi finishing and finishing. Besides this sequence of operations using CAM system algorithm we must consider the wright tool selection and also parameters for machining tool path generation.

Usually free form are composed of many irregular surfaces with different inclination angles, connected with very small radius which makes the NC program to be very hard to realize [2].

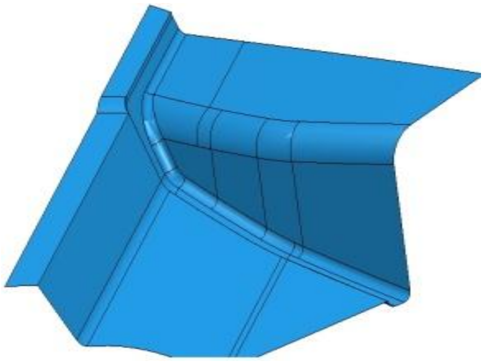


Fig. 1. Free-form.

In this paper we will follow the optimal way of 3 axes processing of free forms with a high degree of difficulty for the tool paths with a small diameter, on areas with an opening angle up to 30 ° as found in the scientific literature and in the calculation methods of many CAM systems [1].

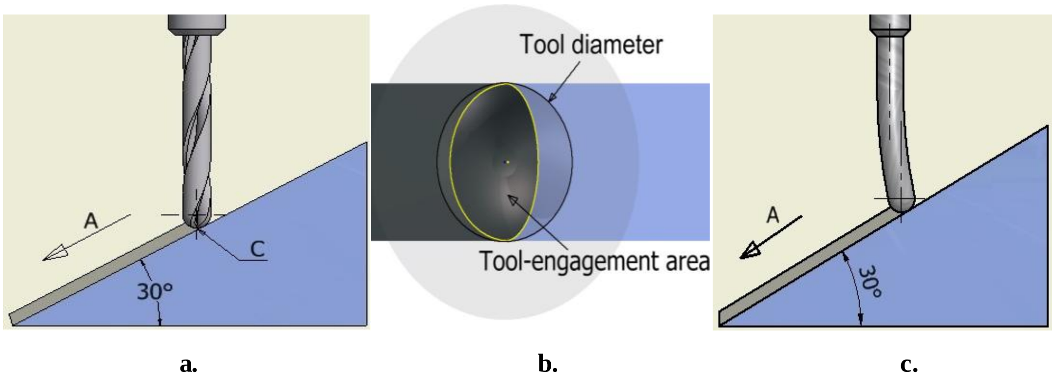
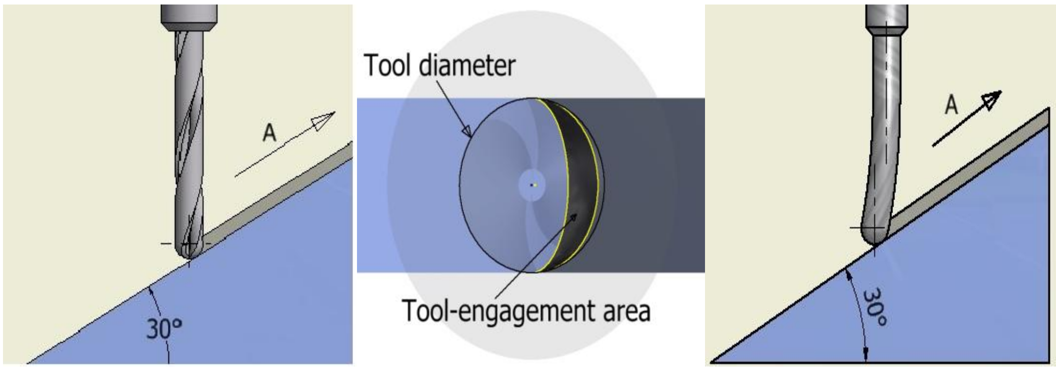


Fig. 2. Tool-engagement area downward milling.

Most of CAM software fails to control the process when it comes to processing surfaces that have an inclination of up to 30º or over 30º. In the process small diameter milling type Ball Nose end mill, a series of problem occurs when the direction of advance (A) of the tool is in descent as shown in Figure 2a. In this situation the tool will have a higher load, generating traces of vibration on the surface. The Ball Nose end mill effort is much higher in the direction of advance as the load is higher on the diameter of the tool Figure 2b and the speed in point C is zero. Because of this the tool tends to have a deflection and automatically is drawn to the piece Figure 2c which will lead to vibrations on the piece surfaces and even tool breakage [4, 5].



a. **b.** **c.**

Fig. 3. Tool-engagement area upward milling.

In the 2nd case when the tool will move upwards Figure 3a, the effort will be lower Figure 3b and the tool will be pushed to the exterior of the piece Figure 3c and will lead to a safer processing eliminating the risk of tool breaking.

Knowing those two aspects of ramp processing we will approach the processing of complex surfaces with CAM software, considering the calculation algorithm of the software and the specifications given by the specialty literature.

For this is considered a practical application that consists in achieving a mold for the part shown in Figure 4.

Fig. 4. Part.

Mold resulting from this analysis, design and practical realization is presented in Figure 5.

Fig. 5. Mold made from this study.

Case study 1.

The algorithm used by Power Mill CAM software for surfaces that have a curve which can get even up to 90º, involves a split in two types the processing path. The first is stitch shaped from 30º up to 90º, and the 2^{nd} from 0º to 30º and follows the shape of the part Figure 6.

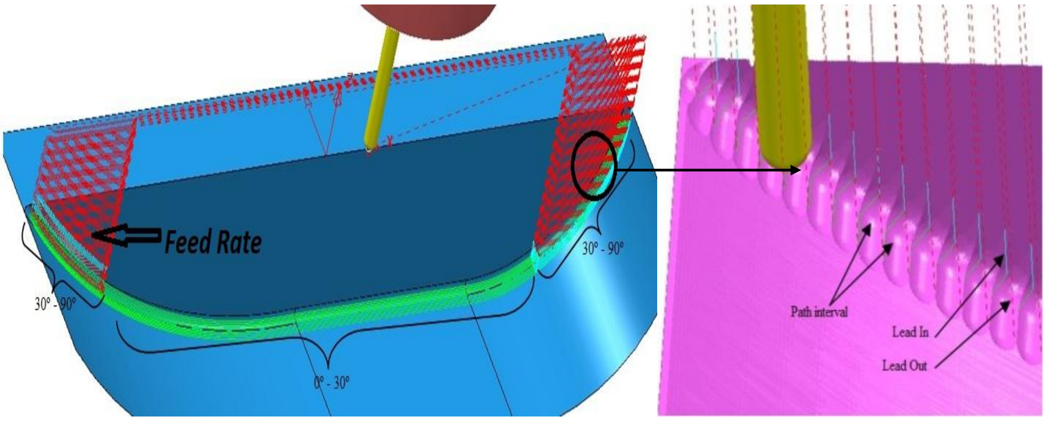


Fig. 6. Processing stitch type on an angle higher than 30º.

This option makes the production time to be longer and the surface will be damaged because of the tool in and out and also because of the rapid advanced movements that the tool executes in order to make the stitch type processing.

After this processing strategy, part surface will have a higher roughness due to tool paths stitch type formed by step path.

To achieve a better roughness is necessary to introduce small steps between paths, which will automatically increase production time through the multitude of new paths created.

Case study 2.

To achieve a batter surface the user may be able to impose some parameters to the CAM software which will improve part surface. Imposing these parameters consists in forcing the tool cutting angle up to 90°, on the piece surface.

Usually for making a connection surfaces are used tools with increasingly smaller diameters to achieve the final surface imposed [6]. The result of this method will lead the tool all over the route that will be processed, and next the path is cut into two parts. This cutting is done to introduce advance uphill direction that the tool will execute on the workpiece free form. Changing the advanced direction will result in a small roughness, because the direction of advanced will be from 0° up to 90° and automatically all the tool inputs for achieving radius connection will be from the point where the cutting was made [7, 9, 10].

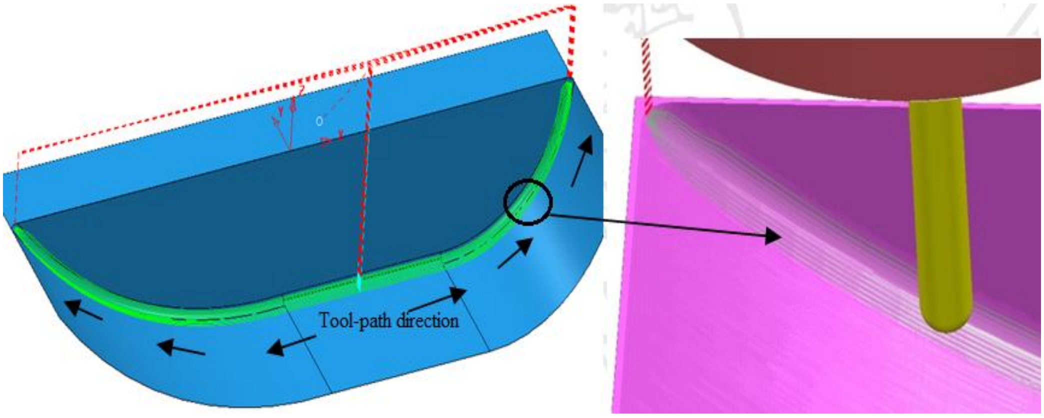


Fig. 7. Processing the entire surface of the workpiece up to an angle of 90°.

Using this strategy by following the free form profile makes this a safer processing method because of the arrangement routes that tool will use which are optimized to work from outside to inside in order minimize the material waste Figure 8 [8].

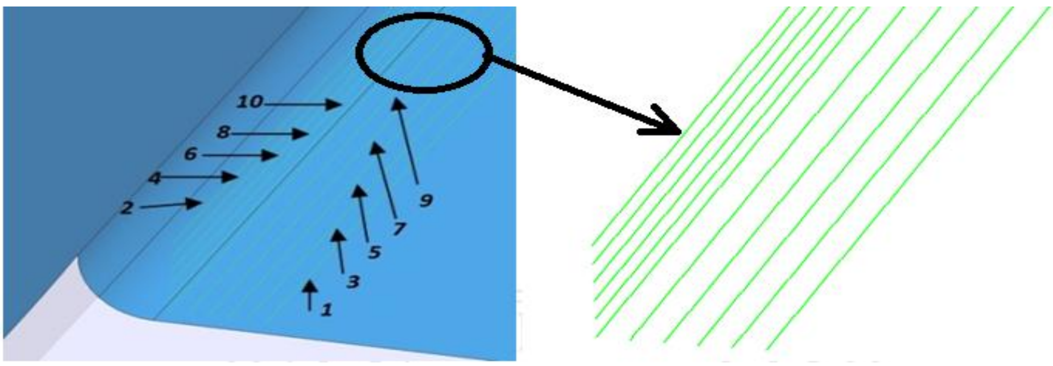


Fig. 8. The ordering tool path.

Fig.9 Surfaces made by the method of Case Study 2

Conclusions

In the first stage of mold processing with PowerMill software has one obtained a series of surface finishing problems, which generated the search for a new solution which is described in the Case study no. 2.

The second case study demonstrates the effectiveness of the processing of free forms by controlling tool paths through processing and improvement of safe work surface. The following conclusions were made:

- Removing material is progressive, resulting in lower cutting forces, which leads to small deflection of the tool in use.
- Advantages in ramp processing significantly reduces vibrations and shocks during processing due to lower load on the tool diameter, increasing tool life by about 20%.
- By removing the stitch type strategy Case study 1, the processing is more stable and easier to follow.
- The result of the protocols of Case study 2 was verified by practical experiment, showing roughness surfaces much better and processing time by 15% lower.

This result was obtained by moving the tool along the work surface and uses an angle of inclination greater tool path, enabling the tool to have constant contact with the part surface.

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