



TOOL PATH GENERATION AND TOOL SELECTION FOR 2D CNC ENGRAVING

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Abstract: *In order to improve engraving efficiency, proper tools must be used along with adequate machining parameters. Tool path generation is the key ingredient in achieving a fast and reliable design by improving the machining process in both speed and quality. Taking in consideration the fact that usually there is no Z-level machining, thus eliminating the roughing and finishing stages, the machining time is mainly set by the complexity of the 2D shape and the material of the workpiece. The tools used are small angled cutters or end mills up to 3mm in diameter. This paper proposes a series of guidelines that will optimize the CNC engraving process.*

Key words: *2D CNC engraving, workpiece*

1. INTRODUCTION

Computer numerically controlled (CNC) machining operations are based on a virtual model defined in a computer aided design (CAD) environment. In order for the machine to be able to “read” this model, the tool must be guided along guidelines that best approximate the model. These guidelines are called tool paths and are generated in different computer aided manufacturing (CAM) software.

Engraving is the form of milling that takes place on the surface of the workpiece, at a relatively small depth of cut. This operation takes place mostly on plane, 2D surfaces, but it can also be done on 3D object with the help of 4-axis or 5-axis CNC equipment. The materials most used are plastics like ABS and different types of acrylics for the advertising industry. In the industrial domain engraving can be made on Aluminum slates as instruction tags or warning signs. The thickness of the

workpiece may vary, for plastics, between 1.5 and 10 mm and for Aluminum between 1 and 2 mm.

The engraving process can easily be considered a “high speed milling” process (HSM). This term is used to describe milling processes with small diameter tools (≤ 10 mm) at high rotational speed ($\geq 10,000$ rpm). In order to achieve an efficient HSM there must be assured a correct selection of cutting tools and a fair evaluation of tool path over the shape design. [6]

The entire engraving process starts from designing a 2D shape or contour, continues with generating the tool path program in CAM software and transmitting it to the CNC computer unit and ends with the machining of the workpiece.

The tools used in engraving processes are mostly profiled cutters depending on the nature of the design. The most common tools used are presented in figure 1 (adapted from <http://www.antaresinc.net>).

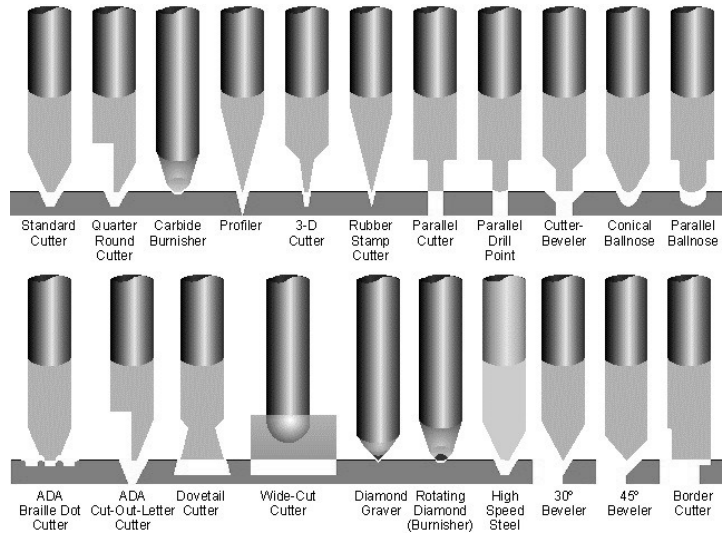


Figure 1. Types of engraving cutters.

Engraving cutters are used in designs that contain elements smaller than 1 mm, like small text or logos, name tags or different labels. The cutting depth of these design are also relatively small, rarely exceeding 0.5-2 mm. Thus, there is no need is using roughing and finishing stages, the machining takes place in only one pass over the entire design. In this case, if using plastic materials, the tool wear is far more reduced than in the case of metal workpiece machining.

2. DESIGN AND EVALUATION OF 2D SHAPES

In order for the design shape to be recognized by the machine, it has to be created in a coordinate system, so that the CNC equipment can identify the position of every point of that shape. These data can be maintained from CAD systems to CAM systems with the help of vector graphics. In figure 2 we have the outline of an A4 page format and the coordinates of the midpoint of its height segment.

There are two conditions required by the CAM systems when working with vector graphics:

- The outline does not self-intersect;
- The outline consists of closed contour.

When an outline self intersects or two contours intersect, they can be joined together using the weld or unify command from the vector editing software, like showed in figure 3.

A4 outline:

Width: 297.000 millimeters
 Height: 210.000 millimeters
 Center: (148.500, 105.000) millimeters

Midpoint coordinates:

(0.000, 105.000) millimeters

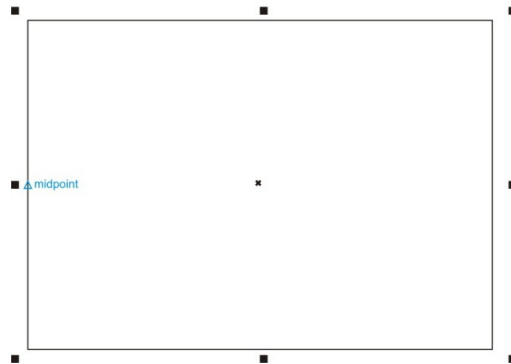


Figure 2.Coordinates of the midpoint of a rectangular shaped vector.

The open contour can be identified with the fill command. An open contour is in fact a complex line, and cannot be filled with color; only a closed contour can be filled.

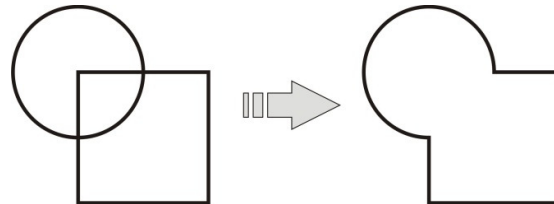


Figure 3. Eliminating the contour intersection.

Apart from these conditions, to create a good design for machining, we need to identify its elements. If we have more than two vectors

overlap than the outer outline is the boundary and the inner outlines are called islands [1]. Figure 4 illustrates these elements on the classic ABC.

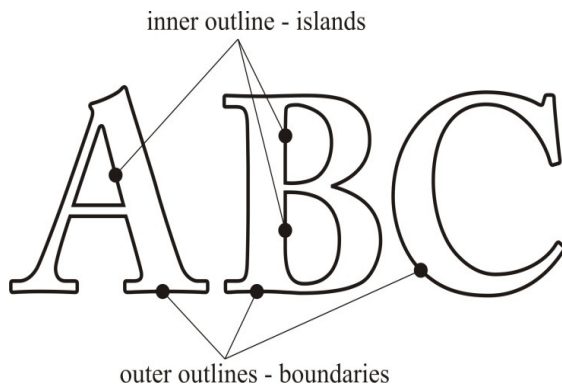


Figure 4. Identifying a vector's outlines.

3. TOOL PATH GENERATION

Choice of tool path is essential in milling operations. Furthermore it has a bigger impact on the engraving process because of the small details in the design. The tool path determines the axial depth of cut that controls the cutting force while machining [7].

Considering the reduced thickness of the workpieces used in engraving processes, there is no use of Z-level machining, thus tool path consist of only one pass milling operation [12]. A tool path represents a series of curves that Besides knowing the types of outline in a 2D design graphic we must also pay attention to the complexity of the design [9]. For every closed contour the generated tool path is divided by the CAM software into sections. Each section has a different start point [2]; the tool takes every section randomly or in an order defined by user. The more angles and curved lines in the outline, the more complex the design gets, thus the design will be divided into more sections, which leads to increased machining time [11]. Font characters do not defer much from one another. Figure 6 illustrates these using 3 types of fonts, with a different degree of complexity. First two design both have 5 start point (marked by black dots) for the generated tool path, while the third has 7 start points due to increased number of corners.

are linked together forming a single path that guides the tool when engaged in machining operations [3].

The most used technique of tool path generation is called iso-parametric. The iso-parametric method works with lines and curves with constant parameters to create the tool paths. [4] the cutter follows this curves in a one-way direction

Figure 5 presents the use of this kind of tool path on the simple shape of the letter “A” regarding to the types of outline described in figure 4. When choosing only one outline, the tool path fills the entire area within this outline (figure 5 a). In order for the tool path to be complete we need to choose both the inner and outer outlines, thus the islands created will not be machined.

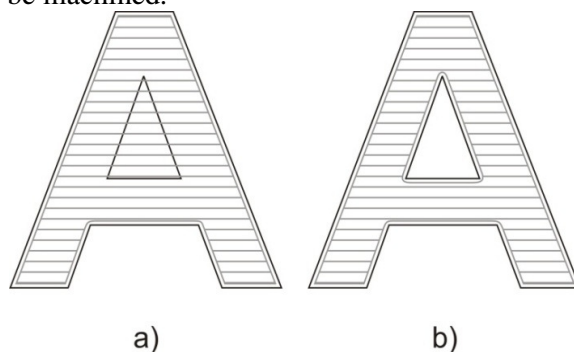


Figure 5. Tool path generation for selected outlines: a) boundary; b) boundary with island.

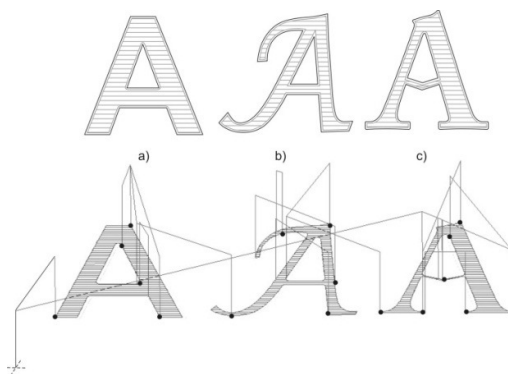


Figure 6. Start point for 3 fonts based outlines.

Now that we have fully defined the outline of the design, we can choose the appropriate tool clearance strategy. For 2D shapes we have two possible strategies: raster and offset. The two strategies are illustrated in figure 7 using both straight and circular lines. For the raster

strategy the user can change the angle of the tool path (in figure 7-a the circle shape's tool

path is at 90° off that of the square), and for the offset strategy the user can change weather the start point is in the middle or on the edge of the outline. Both strategies assume a single continuous pass of the tool for every individual section.

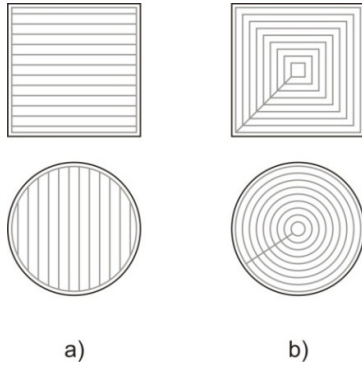


Figure 7. Tool clearance strategies: a) raster; b) offset.

4. TOOL AND MILLING PARAMETERS SELECTION

In order for one to be able to machine the designed shapes, one must have knowledge of the manufacturing processes [5]. Milling operations requires decisions about both the material and the tool. The most common tool used in engraving processes is the profiler cutter. Its advantages are long life due to small cutting depth, the fact that it can work at high spindle speed (up to 12.000-15.000 rpm) and it is easy to recondition once its cutting edge wears out [10,13]. One of the main disadvantages is that it can easily break due to the small tip dimension (0.1-0.2 mm).

The machining parameters in milling operations are: cutting speed, radial and axial depths of cut, feed, and number of passes [8]. The geometrical dimensions of a cutting tool are presented in figure 8. Here we can also choose the parameters for one specific tool; the tool path generated using this tool will have the same parameters throughout its entire machining [14]. The image is completed by the photo of two such tools that were used during the cutting tests. The first tool presents the cutter with a 10° half-angle tip; the second tool has a 15° half-angle tip. Both tools have a 0.1 mm tip.

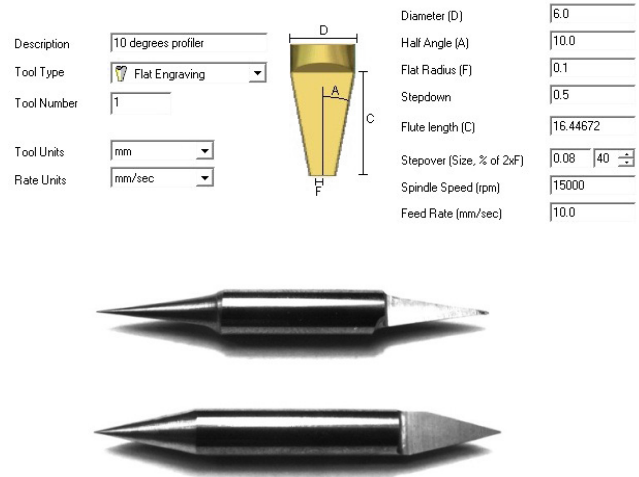


Figure 8. Machining parameters for profiler cutters.

This kind of cutters can be used successfully for engraving ABS material of 1.5 mm thickness and different acrylics of up to 6 mm thickness. For the ABS we can use a spindle rotation around 10 and 12.000 rpm and a feed rate of 7 to 10 mm/sec. When working with acrylics, due to the roughness of the material, the spindle speed should not exceed 8.000 rpm and feed rate should not be more than 5 mm/sec. The area that they can cover at HSM parameters is up to an A3 format, with island smaller than 1mm. If the design has no boundaries smaller than 2 or 3 mm than we can easily use end mills of 2 or 3 mm (figure 9).



Figure 9. End mills: a) 3mm; b) 2mm.

The tools engaged in milling and engraving processes, apart from a good surface finish, also help in achieving a good edge quality. This is possible when tool path are generated parallel or perpendicular to the machine tool axes. [7]

5. CUTTING TESTS

The following cutting tests were performed on a three-axis CNC equipment. The tools used are both cutting profilers and 3 mm end mill. In figure 10 we have a simple font test for 18 and

22 points text. Those from the top of the image are in regular format and those from the bottom are bolded.



Figure 10. Profiler cutting test: fonts.

Next we have three more examples made with the profiler tool in figure 11. The first two were made using the offset clearance strategy, while the tool path in the last one followed only the outline of the boundary.



Figure 11. Profiler cutting test: different shapes;

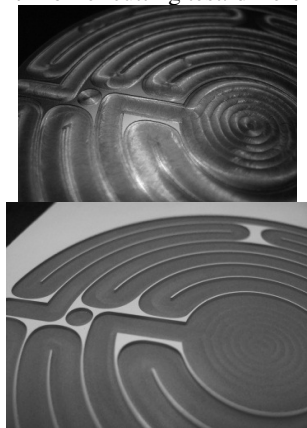


Figure 12. Maze cutting test.

The last set of tests was made using the 3mm end mill (figure 12). Using a maze design, the first test was made in Aluminum and the machining took about 2 hours. The second test, with the same design, was made in ABS and only took 45 minutes to make.

6. CONCLUSIONS

When performing engraving operations it is important to have good knowledge of both design and manufacturing processes. A shape design made right from the beginning will lead to fewer errors in establishing the machining parameters. And furthermore, choosing the appropriate machining parameters is necessary to ensure the requirements of both safety and quality. The result of these choices will reflect in productivity, cost and quality of the final product.

The engraving process itself presents a certain freedom in creating a complex design, fast material removal rate and high quality machined surfaces that do not require any additional finishing operations.

The two most important aspects necessary for achieving a high quality engraved design are: tool path selection and adequate machining parameters. The right choice regarding different elements of the machining process can only lead to a successful engraving operation.

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Generarea traseului de lucru și selecția sculei la gravarea 2D pe echipamente CNC

Rezumat: În vederea îmbunătățirii eficienței la gravură, trebuie folosite sculele potrivite împreună cu parametrii optimi de prelucrare. Generarea traseului de lucru este elementul principal în obținerea rapidă a unui design fiabil prin îmbunătățirea vitezei și calității procesului de prelucrare. Luând în considerare faptul că în cazul gravurii nu se realizează o prelucrare accentuată pe axa Z, eliminându-se astfel etapele de degroșare și finisare, timpul de prelucrare se stabilește în funcție de complexitatea formei 2D și a materialului din care este realizat semifabricatul. Sculele folosite sunt cuțite de gravură sau freze de până la 3 mm diametru. Prezentul articol propune o serie de linii directoare care ajută la optimizarea procesului de gravare pe echipamente CNC.

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