CUTTING TOOLS SELECTION THROUGH CAD RESOURCES

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Abstract:
Existing commercial CAD/CAM systems allow the user to generate the cutter-path for machining a pocket by using only a single cutting-tool size. Therefore, to avoid potential problems, such as gouging and unmachined areas, the user tends to choose the size of cutting-tool in a conservative manner. This can result in longer processing time and higher production cost than those that be achieved by using multiple cutting-tool sizes to machine a given pocket. This work deals with the development of a methodology for automatic selection of cutting-tools using available resources in systems CAD. The machining states are organized in way that system CAD can determine for each option of tool dimension the value of the length of cutter-path. With this data, a method of dynamic programming is applied that identifies which tools will provide one better situation of lesser machining time. This implementation uses available resources in systems CAD, this in case that the AutoCAD, as determination of trajectories in offset and use of commands in form of program through the Autolisp language.

Keywords: *Cutting-tool selection, Pocket Cutter-path, Cutter-path CNC.*

1. Introduction

With the use of computer in the cutter-path processes, specially by the application of CAD/CAM (*Computer Aided Design/Manufacturing*) systems for the generation of programs for Computerized Number Command equipments (CNC), the manufacture process of mechanic pieces got more efficient, with more precision and quality, but it is far of getting its total potential (Veeramani & Gau, 2000).

For 2 ½ D pocket machining, CAD/CAM commercial systems allow the generation of a cutting-path that uses only a cutting-tool, specified by the operator. To reduce the material left in the cavities corners, the tool diameter choice tends to be conservative. The selection of small diameters provides smaller unmachining area. However, it results in a larger amount of looping passes and as a consequence a larger machining time.

Proposals of optimizing the cutting-path, seeking the best diameter choice of the cutting-tool and the use of more than one tool to the manufacture of 2 ½ D pocket, are presented by different researches (Veramani e& Gau, 2000). These studies show how those actions can contribute for the reduction of machining time, therefore in CNC machines the tool change can be done in seconds. These techniques apply computational algorithms that use advanced math expressions for geometric calculations.

The object of this paper is to propose an application methodology of CAD systems programming resources as an implementation alternative of these techniques.

2. Tools-Path

Authors as Held (1991), considered that 80% of the machining operations for the mechanical pieces manufacturing can be realized through 2 ½ D machining, that is the movement in two axles maintaining the third fixed.

The approach presented in this paper is initially based in the proposal of Veeramani & Gau (1997), by considering the machining in two stages: internal machining and corner machining. This proposal of systemizing the 2 ½ D pocket cutter-path permitted the implementation of methods follow detailed.

The 2 ½ D machining is characterized by the tool movement in a limited surface by the pocket border. Usually the distance between the cutting-paths, in successive looping operations, is realized considering the cutting width or job penetration (Stemmer, 1992) recommended by the tool manufacturer.

The most common strategies are:

2.1. Zigzag

It consists of carrying out parallel movements in a determined direction into the pocket to be machined (illustration 1). In this process, there is a remaining material to be removed from the pocket border, because of tool direction changes.

Therefore, in this kind of trajectory it is necessary the removal of the saliencies left by the tool. It is done by parallels movements on the pocket edge profile. It means that, besides the zigzag movements, there is a movement equidistant to the border to remove the material left (illustration 2).

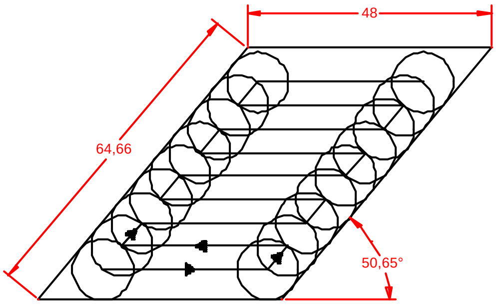

Illustration 1: Initial trajectory in parallel trajectory (zigzag)

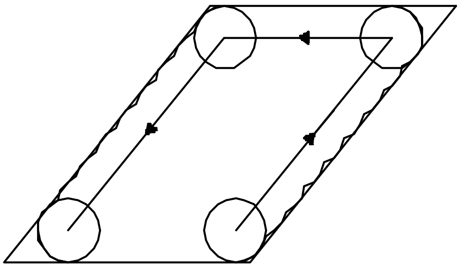

Illustration 2: Final trajectory equidistant to the border

2.2. Offset

It consists in generating equidistant or parallel trajectories to the pocket border (illustration 3). In this case, the pocket laterals would be already cleaned, remaining just the pocket corners to be machined.

According to Tsuzuki & Moscato (1995), the offset machining strategy on the border uses the concept of change elements from the border parallel to define the cutting-path.

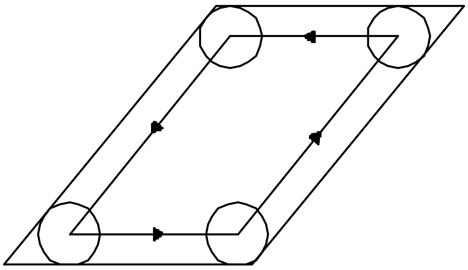

Illustration 3: Inicial trajectory using offset

3. Methodology

In this paper, it is considered the trajectory equidistant to the border method (offset), divided in two stages: internal machining and corner machining. The proposed methodology determines the cutting-path through graphic functions of a CAD system (Autodesk, 2002). The technique was implemented by programmating sources available at CAD to applicatory program elaboration (Gaál, 1999).

3.1. Internal cutter-path

To generate the cutting-paths using CAD commands, some steps must be followed:

a) Transform the border lines of the pocket design in a closed polygon (pline)
b) By the offset tool use, generate trajectories of the cutting-tool from the border element. Each trajectory corresponds to a stage of the looping operation. The distance between these trajectories will be equal to the cutting width specified to the cutting-tool (illustration 4). It must be observed that only cutting width values less or equal to the tool radius guarantee the total removal of the material. The internal machining is done by a unique cutting-tool that will be selected according to the algorithm described at 3.3 item.

c) The ending condition of the creation process of offset lines is the identification by the CAD of the execution impossibility of this function.

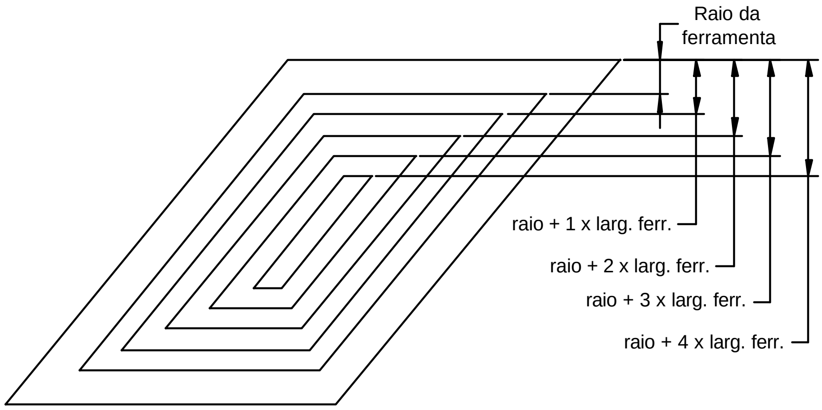

Illustration 4: Consecutive offsets of the border line

3.2. Corner cutter-path:

This stage is characterized by the removal of the unmachined material with the tool used in the internal machining (illustration 5). To generate the cutting-path by using CAD commands, aiming a systematization of this procedure, we follow the next steps:

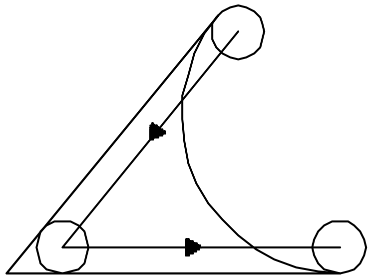

Illustration 5: Initial part of the corner machining

a) By the use of offset tool, generate a cutting-tool trajectory from the external board of the corner with equal tool radius removal.
b) With the same CAD tool, generate some consecutive trajectories of the corner external border, with distance between them equal to the cutting width specified to the tool.
c) The ending condition of the trajectories generation is the situation which the object designed does not intercept the corner area anymore;
d) At this proposal, the movement sequence of the toll will be A – B – C – D – E – F – G – H, with nor retractions nor empty movements (illustration 6);
e) The points A and C are obtained at the final position of the first cutting line;
f) Generate a copy (illustration 6 – a) (offset) of the circumference left by the larger tool, for the internal side of he corner;
g) The points D, F, and G are obtained at tangency position of the previous trajectory cut and from the circumference a (illustration 6).

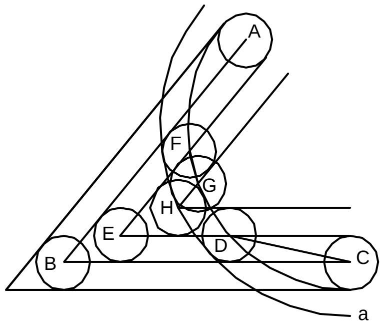

Illustration 6: Corner machining sequence

3.3. Optimized Selection of Cutting-tools

According to Oliveira & Tsuzuki (1999), the systematization of the machining strategies allow the application of a selection method of cutting-tools based on dynamic programming. This method allows the choice, into a determined group of tools, of what sequence of use guarantee a shorter machining time. The method is really simple and it is simple implemented.

In this paper is presented an alternative for this procedure to be applied in CAD systems. To generate a choice algorithm for the best cutter-tool to a 2 ½ D pocket, it was developed a computational system using resources to the development of applicatories (Gaál, 1999) in a platform CAD (Autodesk, 2002). The algorithm implemented follows the process below:

a) Generate cutting trajectories of the internal part, with all cutting-tools available to the process, totalizing the distance covered by each one;
b) For each corner left, by each one of the tested tolls above, generate corner trajectories as described above;
c) Calculate the machining time of each tool through these results and the respective advance speeds recommended;
d) Structuralize the data according to the format presented in table 1. In this table, the tool index follows the decreasing order of the diameter value. The time t_i represents the machining time just with the index *i* tool (first line in the table), with *i* varying from 1 until the number of tools *n*. The times t_{ij} are caculated by the tool time *i* , considering the use of the tool *j* in the previous operation (interior of the pocket).
e) Considering that the smallest tool selected is the one that satisfies the allowable comer radius, it is gotten from *n* column the shortest machining time t_{ni}. This represents that the shortest machining time, using *n* tool (smallest diameter), occurs when the tool *i* (with t_i time) was previously used to machining the interior of the pocket;
f) The same procedure must be repeated for the *i* column of the table. So, the smallest value of this column indicates the tool to be selected in the previous operation;
g) The ending condition of the tool selection process occurs when the shortest time of the column analyzed is the value contained in the first line, since this data represents the time of the respective tool, without considering the use of other tools (item d).

Stage	**Tools**					
	1	2	3	4	...	n
0	t_1	t_2	t_3	t_4	...	t_n
1		t_{21}	t_{31}	t_{41}	…	t_{n1}
2			t_{32}	t_{42}	…	t_{n2}
3				t_{43}	…	t_{n3}
…					…	…
n-1						$t_{n(n-1)}$

4. Results

To the pocket machinig exemplified (illustration 1) there are available tools with 20 mm, 16 mm, 12 mm, 8 mm, 4 mm and 2 mm diameters. The table 1 shows the length values of the cutting-path (mm), determined for this pocket with the available tools.

Tool radius (mm)	**10**	**8**	**6**	**4**	**2**	**1**
Stage/tool	**1**	**2**	**3**	**4**	**5**	**6**
0	121,866	202,359	303,523	487,462	1096,79	2286,689
1		16,905	33,810	50,715	86,335	176,632
2			16,905	33,810	56,812	112,055
3				16,905	33,810	62,757
4					16,905	18,011
5						8,452
Total	121,866	219,265	354,239	588,893	1.290,653	2.664,596

Table 1 – Cutting-path length for available tools (mm)

Considering the advance speed values to the existent tools, there is a new table with the accumulate times to the machining pocket, being the exchange tool time of 5 seconds. With these data, it is possible to determine which tools provide the shortest machining time.

Tool radius (mm)	10	8	6	4	2	1
Advance speed (mm/s)	**2**	**2**	**2**	**2**	**1**	**1**
Stage/tool	**1**	**2**	**3**	**4**	**5**	**6**
0	**60,933**	101,180	151,762	243,731	1.096,790	2.286,689
1		**74,386**	82,838	91,291	152,268	242,565
2			114,632	123,085	162,992	**218,235**
3				165,214	190,572	219,519
4					265,636	266,742
5						1.110,242
Minimum	**60,933**	**74,386**	82,838	91,291	152,268	**218,235**

Table 2. Cutter-path times accumulated, in seconds.

According to the calculated values, it is observed the use indication of three tools, of the six available to pocket machining in minimum time.

In the 1 mm tool column, the minimum time found was 218,325 s, identified in the stage 2. So the tool that precedes it is the tool 2 with 8 mm, which accumulated minimum time is 74,386 s, that identify as previous stage the number 1, with the tool of 10 mm, which time is 90,933.

Therefore, in this case, the select tools are of 20 mm, 16 mm and 2 mm diameters, in this sequence.

5. Final Approaches

The presented results show the method of tools selection for machining of 2 ½ D pockets in machines with CNC, aiming optimize the job and the reduction of machining time. In the examples showed above we used two stages, the internal machining, with a larger radius tool to remove a higher amount of material and the second stage that is the corner machining, using two smaller radius tools to remove the remaining material of the internal machining.

The use of dynamic programming allowed the great selection of the tools that must be used to get the shortest machining time.

The results of pocket how it was exemplified showed a viability of the application of this methodology through the development of applications in a CAD system.

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