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THE CORRELATION BETWEEN COMPONENT SHAPE, PRECISION AND PRODUCTIVITY IN 3-AXIS CNC END MILLING

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Abstract: *The present article presents the influences of part design and the precision of the milling process over the productivity of plastic machined components. These influences create a strong bond between these characteristics, bond that would lead to better results if used properly. The article will propose a series of stages that can improve productivity as well as milling precision and the shape design of components.*

Key words: *CNC end milling, Computer Aided Design, Component design, CAM optimization.*

1. INTRODUCTION

Computer aided design (CAD) has been researched for over four decades and very good result have been obtained in very little time. Nowadays it is not so important if you can make a certain part, but how that part can be machined faster, less expensive and at a higher quality. Now it is a matter of choosing the right process and combining the components of that process in order to achieve more and better parts in less time. However, not all processes are identical, thus regarding different processes will have different production results.

2. CNC MACHINING

2.1 Processes characteristics

Certain materials can only be machined using special types of processes. In figure 1, we have the main categories of processes that gradually remove material from the work piece (adapted after [4]). From all these processes, those that remove material by cutting circular or various shapes are widely used. Furthermore using computer numerical control equipment (CNC) the possibility of creating complex shapes in a large variety of materials can be manufactured very fast and easily.

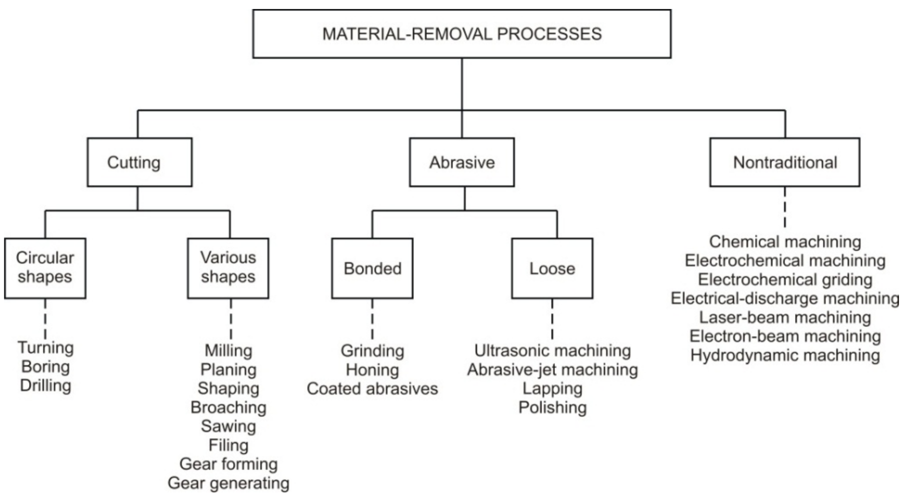

Fig. 1 *The range of material-removal processes;*

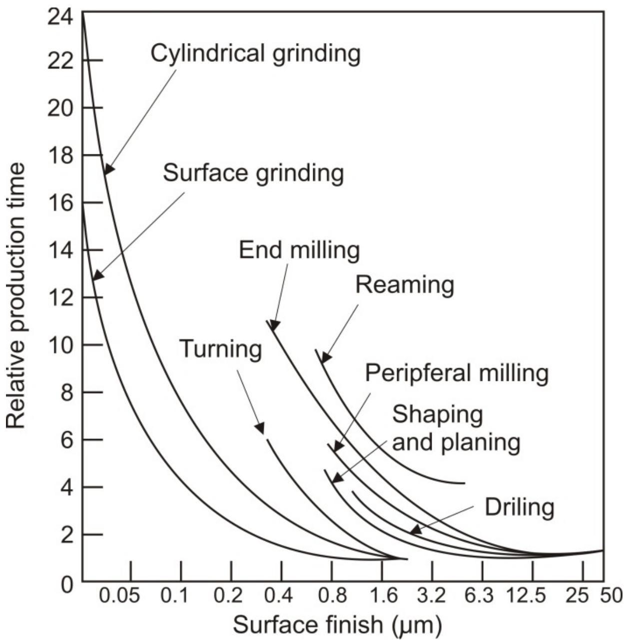

Fig. 2 *Relative manufacturing time as a function for surface roughness for several machining processes.*

In figure 2 are represented several cutting processes, and for each one we have their relative manufacturing time showed as a function of surface roughness. [3]

From this classification, we observe that by end milling we can achieve fair finished surfaces in a relative low production time. Surface roughness is not the only characteristic that influences production time; there is also the complexity of the component and the number of parts that need to be manufactured.

Regarding the end milling process on a three axis CNC milling machine, the present article illustrates the way the shape of the component, precision and productivity influence each other in order to improve the milling process.

Thus, the three studied characteristics consist of the following:

1. Component shape deals with aspects of computer modeling, 2D and 3D characteristics and the level of details included in the model;
2. Precision is given by milling parameters and the work possibilities of the machine;
3. Productivity is set by the number of parts machined and the necessary time to create these parts.

2.2. Components shape

A part is considered an object that has no assembly operations in its manufacture. Parts can also consist of several sequence of manufacturing processes (e.g., casting followed by milling), but parts are not assembled. [2]

Parts can be divided by the role they play in different products. From the point of view of machining, a part is defined by its shape, and the complexity level of that certain shape.

These shapes can be considered features, in the case of 3D parts (ex. cubes, cylinders, for component machined in 2.5D or above) or contours in the case of two dimensional parts (squares, triangles, circles, for engraving operations). All features and contours created with CAD or vector graphics programs are recognized by computer aided manufacturing software (CAM). Shapes become more complex as the number of features increase in 3D parts, and 2D designs, with the increase of both the number of individual close contours and the number of inflection points (where a straight line changes direction) [1].

Regardless of the complexity of the component's shape, precision must be met. Thus, as the complexity increases, for the same precision, the productivity decreases. In order to achieve a fair level of productivity, milling parameters must be set as such, that the obtained parts are within precision, and the whole process fits within acceptable periods.

2.3. Milling parameters

Using milling operations, in general and end-milling in particular we can generate flat surfaces (planes or sides) as well as 2D or 3D curved surfaces, using several finishing stages as showed in figure 3. [4]

In order to generate the machined surface CNC equipment use relative motion between the cutting tool and the work piece. These motions are primary motion and feed motion. In milling operations, primary motion is rotational and provided to the tool, and feed motion is linear and is provided to the work piece [4]. In figure 4 we have a representations of these relative motions.

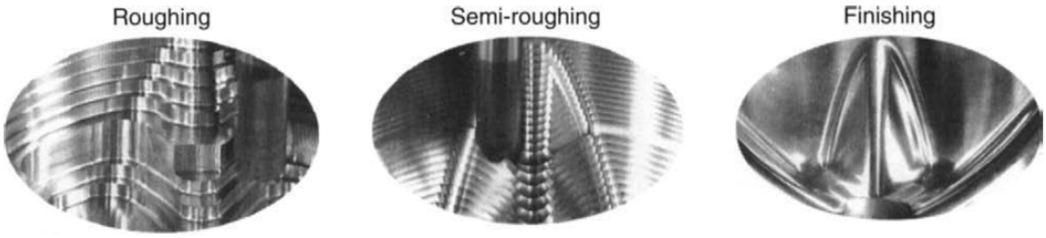

Fig. 3 *Machining stages on a complex 3D shape.*

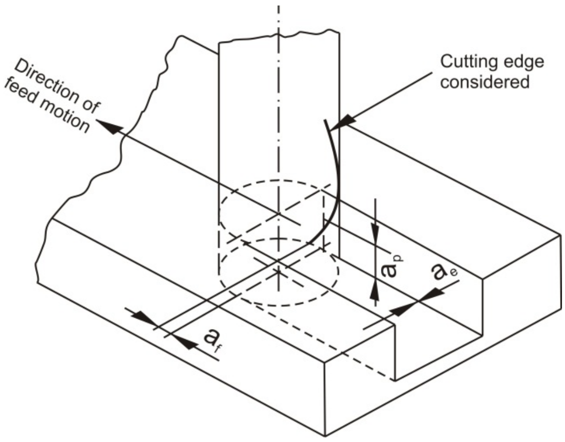

Fig. 4 *The dimension of removed material in end milling.*

The motions are defined by milling cutter speed or spindle speed (1) and feed rate (2).

$$n = \frac{v_c \cdot 10^3}{\pi \cdot D} \; [\text{min}^{-1}] \qquad (1)$$

n - milling cutter speed [min^{-1}]
v_c - cutting speed [m/min]
D - milling cutter diameter [mm]

$$v_f = n \cdot f_z \cdot z \; [\text{mm/min}] \qquad (2)$$

v_f - feed rate [mm/min]
f_z - feed per cutting edge [mm]
z - number of cutting edges

3. EXPERIMENTS

In order to clearly state out the interdependencies between shape, precision and productivity, I have conducted a series of experiments. Using a 3-axis CNC end-milling machine, I varied these parameters on three basic shapes: spherical cap, truncated pyramid and cone. These variations formed 16 different strategies for each shape, resulting in 48 distinct shapes. The 48 shapes were grouped in a 7x7 matrix on a work piece of 380x380. A complete layout generated in ArtCam software is presented in figure 5.

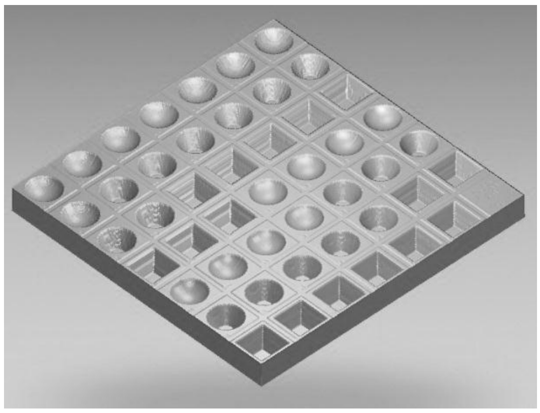

Fig. 5 *Layout of the 48 experimental shapes (ArtCam print screen).*

A unique tool path was generated using a 5 mm end mill tool, for the 48 shapes in the roughing stage. The finishing stage was done individually for each shape, and used different parameters, all coded by the position in the matrix. Finishing used, for half of the shapes, end mill of 2 and 3 mm, and for the other half, ball nose mill also of 2 and 3 mm. Table 1 presents the first set of parameter variation. In figure 6 we have one of the finished surface.

Table 1. *Experimental data (fragment).*

No.	Part shape	Roughing tool	Finishing tool	Feed rate	Speendle	Matrix position	Finishing time
1	Spherical cap	End mill 5 mm	End mill 2 mm	300	8.000	1.1	9’30”
2					12.000	1.2	9’29”
3				600	8.000	1.3	4’50”

4					12.000	1.4	4’49”
5			Ball nose 3 mm	300	8.000	1.5	6’36”
6					12.000	1.6	6’29”
7				600	8.000	1.7	3’18”
8					12.000	2.1	3’16”

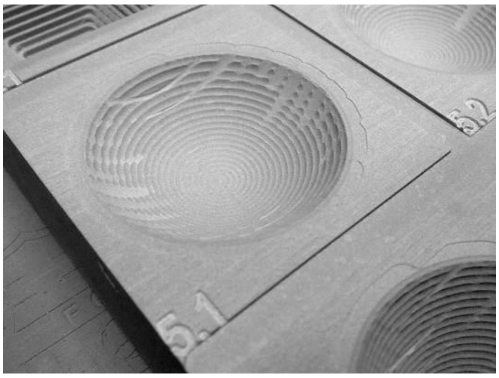

Fig. 6 *Finished spherical cap shape at position 5.1 in the experimental matrix.*

4. Conclusions

Knowing how the shape of component and precision of the machining process are linked together, we can also lower the processing times for both the design process of the model and the actual machining process. The purpose of the tests was to point out the link between component shape, precision and productivity.

Authors suggest that the fully understanding of the characteristics of a certain process and illustrating the connections that exist between these characteristics can lead to improving both the process of designing the component and the actual machining process of that certain part.

5. ACKNOWLEDGEMENTS

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LEGATURA DINTRE FORMA COMPONENTELOR, PRECIZIE SI PRODUCTIVITATE LA FREZAREA PE MASINI CNC IN 3 AXE

Abstract: *Prezentul articol prezinta influenta designului componentelor si a preciziei procesului de frezare asupra productivitatii componentelor de plastic. Aceste influente creaza o puternica legatura intre caracteristici, legatura ce va duce la rezultate mai bune in cazul in care este folosita in mod corespunzator. Articolul va propune o serie de etape ce pot fi urmarite in vederea imbunatatirii atat a productivitatii cat si a preciziei de frezare si a formei componentelor.*

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