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OPTIMIZATION OF THE CNC PROCESSING FUNCTION OF REQUIREMENTS AND CAPABILITIES

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Abstract: The objective of this paper is to adapt the milling cutting parameters, as well as milling strategies, for the complex surfaces executed on CNC milling center. The cutting tools companies often recommend the high values of cutting tools parameters to manufacturing on high-performance machine-tools. The industrial companies do not always have the opportunity to keep up with innovation in the field of cutting tools and to have the latest generation CNC machine-tools with high technical characteristics. Therefore, CNC programmers are forced to adapt the cutting parameters, the technological solutions according to their machine tools, fixtures and cutting tools. The paper come with real application where was underline the balance between what could be and what was implemented, take in consideration the capabilities of the workshop

Key words: *CNC machine tools, CAM applications, milling strategies.*

1. INTRODUCTION

Machine tool companies, as well as cutting tool manufacturers, are innovating, and developing new machines and new cutting tools that aim to increase machining power, with high machining feed systems and rotational speeds, which high cutting tool parameters while reducing manufacturing time, high quality, therefore, high productivity. All these are included in the definition of HSM - High Speed Machining. [1]

There are several definitions of the concept of High Speed Machining, some of them refer to very high revolutions of the spindle (over 15,000 rpm), others, to high cutting-tools parameters. All this leads to the fact that there is no single definition of the concept of HSM, because there are many factors that must be taken in consideration, as well as, a direct interdependence of these factors.

For example, it is not enough to refer only to a high rotation of the spindle of the machine-tools, we must have to take into account many other factors, such as the manufacturing construction of the milling centers like: the rigidity of the machine-tool, the feed systems of the machine's axes - the high precision of translation and rotation movements, thermal deformations as low as possible, etc.

Other definitions are related to the definition of the following cutting parameters:

-Machining at a high cutting speed (v_c).

-Machining with a high spindle speed (n).

-Machining with a high feed rate (v_f).

-Machining with a high removal rate (Q).

A comprehensive definition can be:

As manufacturing with a high material removal rate using a large axial depth of cut (a_p) or large radial depth of cut (a_e) [8].

Figure 1 shows the influence of the cutting speed value on the removed materials quantity, the surface quality, the cutting forces, but also on the wear of the cutting tool (the lifetime of the cutting tools).

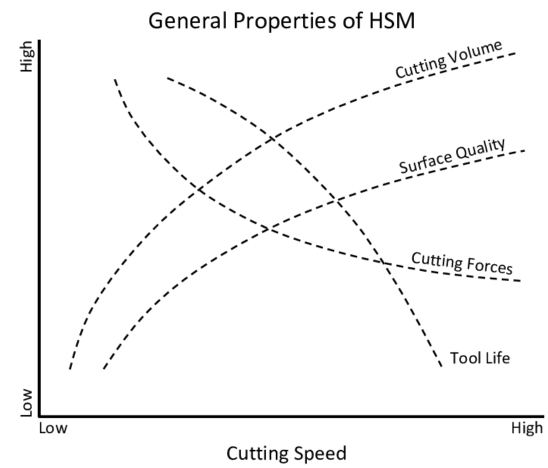

Fig.1. The correlation between cutting speed and chip quantity volume, surface quality, cutting force and cutting tool life

The first attempts at high-speed machining occurred in the early 1920s[3]. About 10 years later, Carl Solomon proposed his definition of high-speed machining: "At a given cutting speed that is five to ten times than in conventional machining, the chip removal temperature at the cutting edge will begin to decrease". Now, his famous included graph has become synonymous with learning about high-speed machining and illustrates what has been the "Solomon graph"

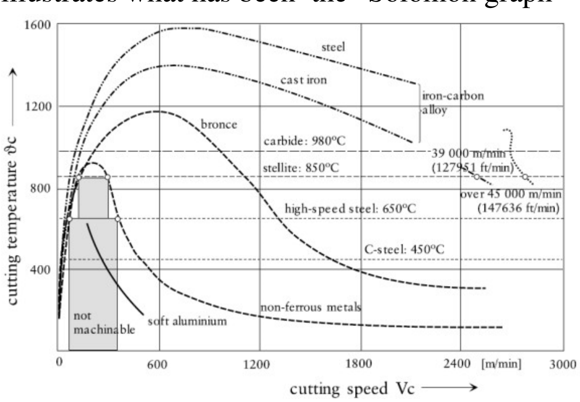

Fig.2. The relationship between cutting speed and cutting temperature

2. THE EXPERIMENTAL METHOD

The starting point of the experiment are the recommendations of the cutting tools companies, the milling strategies and the cutting tools used in the milling proces, as well as of the cutting tools parameters for the materials used in this case study.

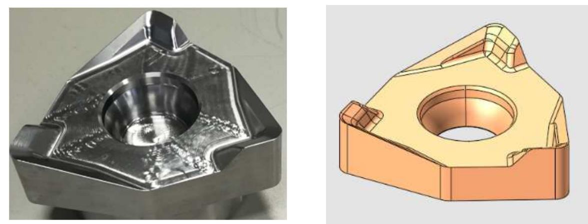

Fig.3. The part what will be manufacturing

Was selected a part with a complex surfaces, basically a removable chipping plate is materialized on a much larger scale. In (Fig. 3),

The raw material used in this experiment is steel 1.1730. Table 1 below presents the name of this in different international standards, the characteristics of the materials, as well as recommendations of the steel manufacturers. (Table 1)

Table 1

International standards

STANDARD	1.1730
DIN:	C45 U
AFNOR:	XC 48
AISI:	1045

The chemical composition (%) of steel 1.1730 is presented in (Table 2).

Table 2

The chemical composition (%)

1.1730		
C	Si	Mn
0,45	0,30	0,70

This steel is a non-alloy tool steel with excellent machinability, good core hardness for minor applications. It is a cold steel obtained by casting, suitable for flame and induction hardening.

This steel is recommended by manufacturers for non-hardened parts to manufacturing injection molds, dies and devices, plates and base frames for molds and dies. (Table 3).

Table 3

The hardness ad the thermal conductivity

Material	Hardness	Thermal conductivity (at 20 ^{0})
1.1730	180-195 HB (≈ 610 - 660 N/mm²)	50 W/m K

The machine tool used is a 3-axis CNC milling center, HAAS Mini Mill, located in the laboratory of the Mechanical Faculty from Timisoara, Romania, with the following characteristics:

Fig.4. Minimill HAAS milling center

TRAVELS
XAxis 406 mm YAxis 305 mm ZAxis 254 mm
Spindle Nose to Table (~max) 356 mm
Spindle Nose to Table (~min) 102 mm
SPINDLE Max Rating 5.6 KW Max Rotational Speed 6000 rpm .To create the technology and the NC program, dedicated software was used to design and manufacture the plastic injection molds. This CAD/CAM software is widely distributed among mold manufacturers, to create the CAD part and generate the NC program. Take in consideration the geometry of the part, the milling strategies used to manufacture the part, were divided into 2:

- 2 ½ axes for the external contour of the part
- 3D milling strategies for the inside complex profile of the part

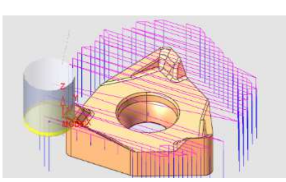

Fig.5.a Plunge milling

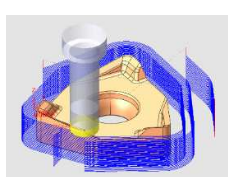

Fig.5.b. Contour milling

2.1. Milling Outer contour:
The external contour milling technology was manufactured by two methods: Plunge milling (Fig.5.a) and contour milling (Fig.5.b) [3].

In the first case, a rigid machine tool with high power is needed. The manufacturing time for this operation is 7 min and 32 sec. As an alternative, the removal of the material can be done using contour milling, with a classic contour milling strategy, with a cutting depth of ap = 1mm, but the processing time is very long: 1 hour, 20 minutes and 41 seconds.

In Table 4 was presented the cutting parameters used [3] the manufacturing times, and in Fig. 6.a and Fig. 6.b are presented the print screens from the CAM software for the two cases presented.

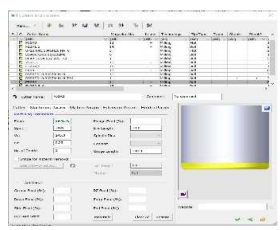

Fig.6.a Cutting tools parameters for plunging

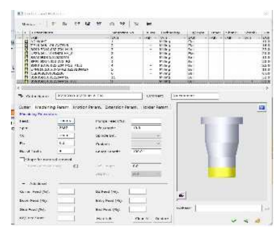

Fig.6.b Cutting tools parameters for contour.

Roughing profile: To manufacture the center hole, the Rough Spiral - Z level milling strategy was used. The manufacturing time was: 8 minutes and 34 seconds. The difference was the limitation to the maximum speed of the machine.

The cutting parameters to manufacturing the inner hole and the milling strategies used are presented in Tab.5[*3].

2.2. Outside semi finishing contour
Two totally different strategies were used for this operation: one has the new milling strategy Volumill and a classic processing strategy: Contour milling strategy. Through Volumill[9], the ability of all active length tool to process with the entire active length of the milling cutter is highlighted versus the classic processing to process at small depths and with successive passes.

Table 4

Roughing Outside contour

Cutting tools recommendation vs Case study		Cutting tools	Case study	Cutting tools	Case study
Machining operation		Outside Contour	Outside Contour	Outside Contour	Outside Contour
Type of operations		Roughing	Roughing	Roughing	Roughing
Milling strategies		Plunging	2Axes contour	2X-Profile Tronchoidal	2Axes contour
Tool	Diameter Dc[mm]	52	32	16	16
	Radius r[mm]	2	1,5	0	0
Indexable insert		yes	yes	no	no
No. of teeth		5	5	5	5
Milling parameters	Vc [m/min]	245	211	380	201
	fz [mm]	0.25	0.071	0.13	0.05
	ap [mm]	43	1	43	43
	ae [mm]	8	0.75*D	0.4	0.3
Part surface offset [mm]		0.4	0,4	0.4	0.1
Speed		1500	2098	7560	4000
Feed		1873	600	10200	1000
Time[h:m:s]		0:07:32	1:20:41	0:03:10	0:00:41

Table 5.

Cutting tools parameters

Cutting tools recommendation vs Case study		Cutting tools	Case study 1	Case study 2
Machining operation		Profile 3d	Profile 3d	Profile 3d
Type of operations		Roughing	Roughing	Roughing
Milling strategies		Rough Parallel	Rough Spiral - Z level	Rough Spiral - Z level
Tool	Diameter Dc[mm]	32	32	32
	Radius r[mm]	1.5	1,5	1.5
Indexable insert		yes	yes	yes
No. of teeth		5	5	5
Milling parameters	Vc [m/min]	240	211	211
	fz [mm]	1	0.3	0.65
	ap [mm]	1	0.7	0.3
	ae [mm]	12.8	12.8	12.8
Part surface offset [mm]		0.4	0.4	0.4
Speed [RPM]		2387	2098	2098
Feed [mm/min]		11935	3147	6818
Time[h:m:s]		0:03:03	0:08:03	0:08:34

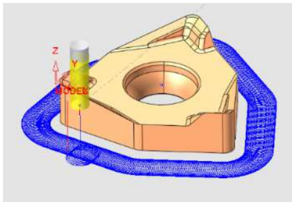
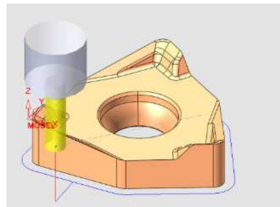

Fig.7.a Volumill strategy **Fig.7.b** Contour milling

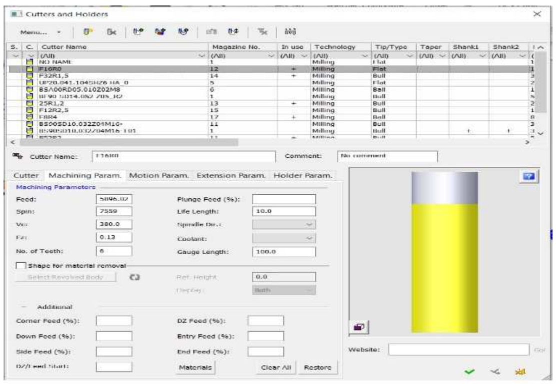

Fig.8. Cutting tools parameters for Volumill

2.3. Internal processing of roughing and semi-finishing

Through this operation, the removal of material from the inside is followed, with a roughing pass using a tool with interchangeable plates (Fig. 9.a) and a semi-finishing with a monobloc tool.

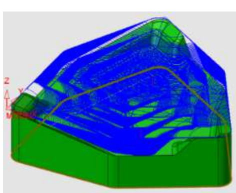
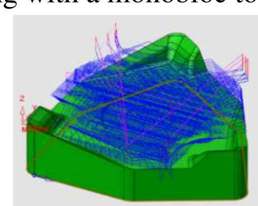

Fig.9.a Roughing profile **Fig. 9.b** Semi-finishing

(Fig. 9.b). In (Fig.10.a) are presented the cutting parameters for internal roughing and in (Fig.10.) the cutting parameter in the case of semi-finishing

The semi-finishing operation represents the release of the corners and radii from the raw material left after the roughing stage, and the preparation of the part from the point of view of the addition (constant addition) for the cutter diameters that follow in the finishing technological process.

For this stage, it was chosen to use 2 milling strategies, namely are re-roughing strategy and a finishing strategy with a constant dept 0.1 mm on the sides of the part. (Fig.10)

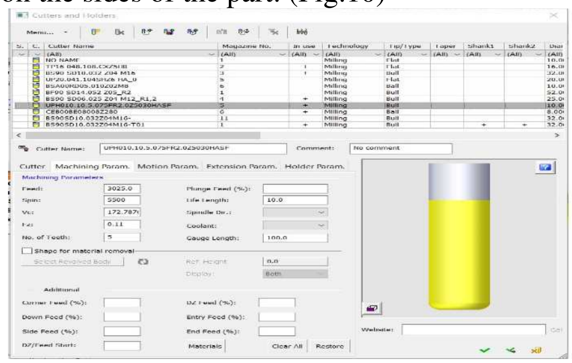

Fig.10. Semi-finishing contour

In Fig. 11, the correlation between the two cutting parameters, namely f_z and a_p, is represented.

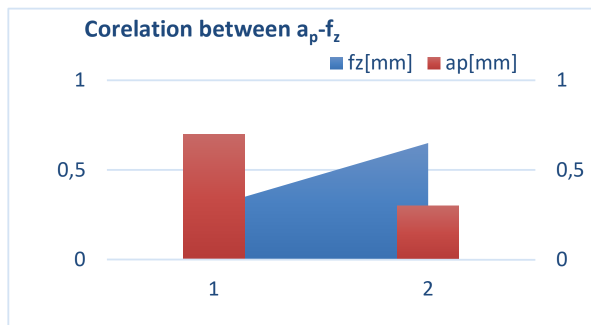

Fig.11. The correlation between the cutting-tool parameters f_z and a_p

By reducing the input step on the Z(ap) axis, the advance on the tooth f_z can be increased, in this way, we can reduce the time of manufacturing.

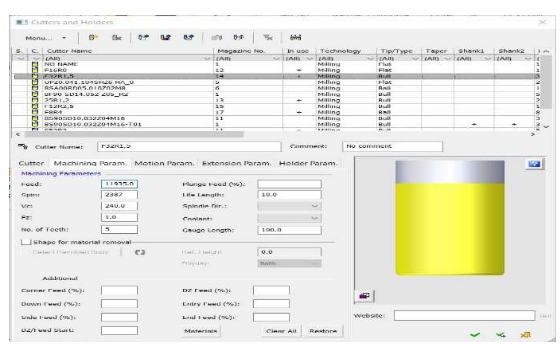

Fig.12 The cutting parameters of the cutting tool during internal semi-finishing operation

Table 6.

The reroughing milling operation.

Cutting tools recommendation vs Case study		Cutting tools	Case study 1	
Machining operation		Profile 3d	Profile 3d	Profile 3d
Type of operations		Reroughing - Semi	Reroughing	Semifinishing
Milling strategies		Rough Updated	Rest milling	Z level + Horizontal
Tool	Diameter Dc[mm]	12	10	10
	Radius r[mm]	1.5	2	2
Indexable insert		yes	no	no
No. of teeth		2	5	5
Milling parameters	Vc [m/min]	250	173	173
	fz [mm]	0.2	0.11	0.11
	ap [mm]	0.8	0.25	0.3
	ae [mm]	4.8	2	4.8
Part surface offset [mm]		0.1	0.4	0.1
Speed [RPM]		6631	5500	5500
Feed [mm/min]		2650	3000	3000
Time[h:m:s]		0:07:05	0:02:48	0:06:51

Table 7.

The finishing milling operation

Cutting tools recommendation vs Case study		Cutting tools	Case study 1	Case study 2
Machining operation		Profile 3d	Profile 3d	Profile 3d
Type of operations		Finishing milling	Finishing milling	Finishing milling
Milling strategies		Z-Level	Z-Level	Z-Level
Tool	Diameter Dc[mm]	8	8	8
	Radius r[mm]	4	4	4
Indexable insert		yes	yes	yes
No. of teeth		2	2	2
Milling parameters	Vc [m/min]	320	150	150
	fz [mm]	0.2	0.12	0.08
	ap [mm]	0.1	0.1	0.1
	ae [mm]	0.1	0.1	0.1
Part surface offset [mm]		0	0	0
Speed [RPM]		12732	5950	5950
Feed [mm/min]		5092	1422	1000
Time[h:m:s]		0:08:03	0:29:03	0:40:43

In (Tab.6) was presented the reroughing operation and the cutting parameters used, and in (Tab. 7) was presented the cutting parameters for finishing, both for the tool manufacturer's recommendation and for the analyzed case. [*3]

To be able to use large processing feeds, a monobloc milling cutter with 5 flutes was chosen and the cutting depth was reduced.

2.4. Finishing operation

For this last operation within the technological itinerary, a ball mill with a removable carbide plate with a diameter of 8 mm and a radius of 4 mm was chosen in both cases.

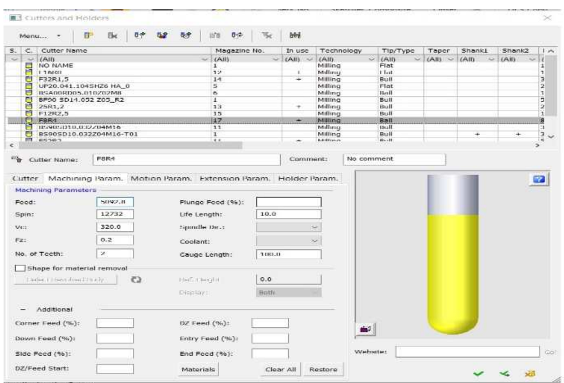

Fig.13. The cutting parameters of the cutting- tool and his trajectories

Fig.14. Two different surface quality of the part

In order to find the most optimal parameters, 2 parts were milled with different cutting parameters, namely f_z, the advance on the tooth, was reduced, thus increasing the surface quality. (Table 7).

In this last stage of milling the part-finishing, the Z(ap) recommended by the tool manufacturer was applied but take in consideration that the machining center used can run maximum rotational speed (6000 RPM), less than half of the recommended on the cutting tool catalog, the milling parameters were optimized in order to increase the quality of the surface.

At the same cutting speed, the best quality of the surface resulted at feed values of 1000 [mm/min], which means that by decreasing the feed per tooth, a corresponding roughness of the surface is obtained, but the processing time increases from 8 minutes to 29 minutes, and with the feed speed by1000 [mm/min], the time of manufacturing is 40 minutes and 43 sec.

3. CONCLUSIONS:

Very often, the manufacturing companies do not have the latest machine tools with high technological characteristics to be able to apply the highest cutting tools parameters recommended by the cutting tool manufacturers, nor the time necessary to carry out experiments and in addition, production cannot be stopped.

Analyzing table 7 and seeing the wide range of processing time (between 8 min. 03 sec and 40 min. 43 sec.), we can see the importance of the correct choice of the machine tool, of the technology that will be applied, considering the initial data's available to the CNC programmer.

The importance of the interdependence between a_p and f_z presented in Fig. 11 is a certification of the correct application of the cutting tools parameters to obtain the required quality of the manufacturing part and a processing time as short as possible.

The purpose of this paper was to present the CAM possibilities of CNC milling manufacturing take in account the technological itinerary, the milling strategies and sure, how to apply the cutting parameters in terms of safety, efficiency, and optimal processing conditions.

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Optimizarea procesului de prelucrare CNC funcție de cerințe și posibilități

Obiectivul acestei lucrări este de a optimiza parametrii de frezare si alegerea corecta a strategiilor de frezare pentru o piesa cu suprafețe complexe, pentru a obține un timp de prelucrare cat mai mic, cu respectarea condițiilor de precizie cerute de desenul de execuție. De cele mai multe ori, producătorii de scule așchietoare recomanda parametrii de așchiere cu capabilități ridicate de prelucrare. Nu întotdeauna, companiile prelucrătoare, au posibilitatea de a tine pasul cu inovația din domeniul sculelor așchietoare si nu toți dispun de mașini-unelte de ultima generație, cu caracteristici tehnice ridicate. De aceea, programatorii CNC sunt nevoiți sa optimizeze parametrii de așchiere, sa găsească soluțiile tehnologice cele mai adecvate, în funcție de centrele lor de prelucrare, de sculele așchietoare si dispozitivele existente. Lucrarea de fata vine cu exemple concrete de optimizare, implementând noile strategii de frezare CNC, versus, strategiilor de prelucrare clasice pe mașini unelte cu comanda numerica evidențiind avantajele noilor facilități de programare CAM in utilizarea pe mașini cu caracteristici tehnice medii.

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