# A Comparative Study Regarding Monoblock CNC Milling Processing

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**Abstract:** *Milling is the processing with the largest share among cutting operations. Temporary and specific optimization of this operation brings significant reductions of the production costs. In the presented paper, authors make a comparative study on the milling machining of a part using the same type of tool, through two different strategies: the classic milling method and the "Vortex" strategy using the monobloc carbide milling cutter.*

**Keywords:** *milling, temporary optimization, carbide monobloc milling cutter, "Vortex",*

## 1 INTRODUCTION

In this paper, two milling processing strategies will be studied, namely the classic milling strategy and the “Vortex” type milling strategy, on a batch of six pieces.

The aim of this work is to minimize the processing time, the tool life and to optimize the costs necessary for the processing of the parts in compliance with the requirements related to surface quality[1].

In order to achieve the objective of the work, the following stages will be followed: the choice and presentation of the used tools - monobloc end mill cutters made of metal carbide; making the CNC programs; processing the batch of parts through the two chosen strategies; measuring the roughness of machined surfaces; analysis the wear of the work surfaces of the cutter; data centralization and preparation of reports; analysis of the results and conclusion establishment.

During the experiment, the number of pieces will be processed, through each strategy, as long the tools last.

## 2 EQUIPMENT PRESENTATION FOR CONDUCTING THE RESEARCH

### *2.1 Workpiece*

In order to carry out the experimental research, it is proposed to process through the two strategies, two batches of identical support type pieces with dimensions of 40 x 110 x 140 mm (figure 1). The semi-finished product is made of S355JR steel.

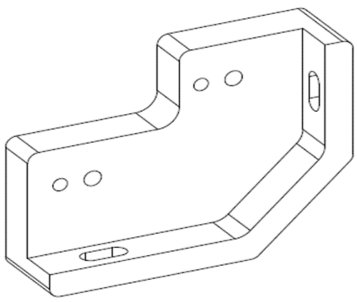

*Fig. 1. The piece which is being processed.*

### *2.2 Machining tool*

A one-piece end mill for roughing and finishing - HOFFMANN manufacturer (figure 2) will be used for processing and study. This type of cutter can be used for both roughing and surface finishing.

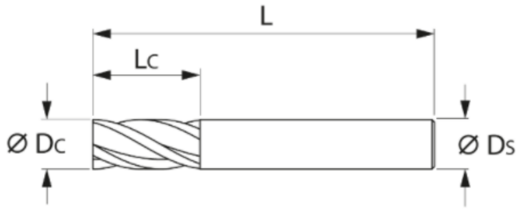


*Fig.2. Milling cutter specifications [2].*

The technical specifications of the cutter are as follows:”Dc - 16 mm; Lc- 35 mm; Ds - 16 mm; L-93 mm; Number of teeth Z - 4; Helix angle - 30 °; Corner chamfer angle - 90 °; Direction of infeed - horizontal, oblique and vertical; Carbide cutter material; Shank: DIN 6535 HB with h6 ”[2].

### *2.3 Machine tool*

The processing of batches of parts were done on a DMG MORI CMX 50U machining center CNC with5 axes (figure 3.).


*Fig.3. DMG MORI CMX 50U Machining Center.*

The technical specifications of this machine center are: “HEIDENHAIN operating system; work area strokes: X =500 mm, Y = 450 mm, Z = 400 mm, B=−5 ° / + 110 °; C = n x 360 °; touch control panel; maximum main shaft speed: 12,000 rpm; work area diameter: 630 × 500 mm; main shaft motor power: 13 kW; tool shop capacity: 30 seats; max length tool: 300 mm; maximum tool diameter: Ø 80; max weight of the tool: 8 kg; coolant both on the outside through the nozzles and on the inside of the tool; overall dimensions: 4400 × 5000 × 2710 mm; maximum weight on the table: 200 kg; total weight of the machine: 4700 kg.

## 3. PERFORMING THE EXPERIMENT

### *3.1. Elaboration of the CNC program*

CAM PowerMill version 2021 is used to develop the program. The stages of the program:

1. Import the 3D model into the PowerMill 2021 CAM software (Figure 4).

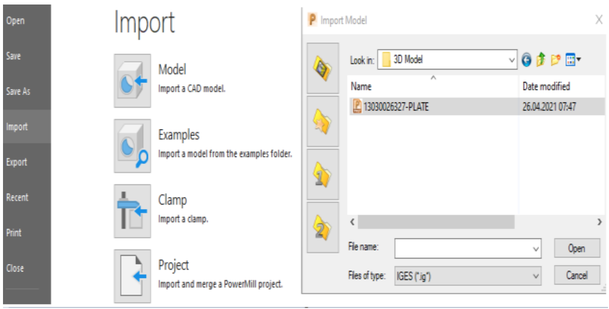


*Fig.4. Import the 3D model into the CAM software.*

2. Positioning the coordinate system or choosing the origin.

The operation consists in pressing the “Workplane” button, with origin from 3 points in the CAM software toolbar and positioning it in the desired place (figure 5).

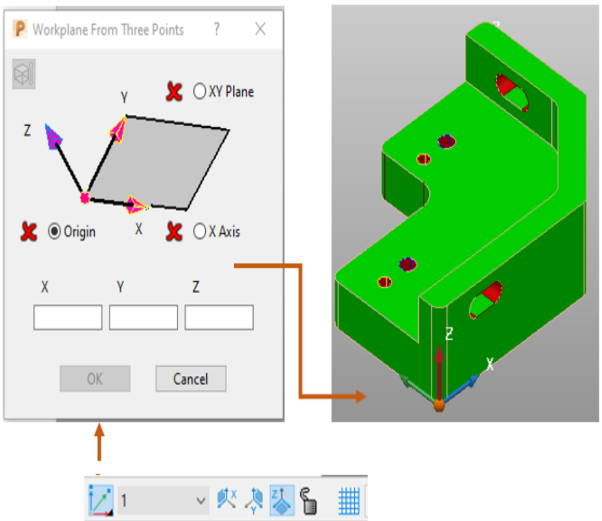


*Fig.5. Positioning the coordinate system.*

3. Definition of the semifinished product.

To define the semi-finished product, access the "Block" icon, the semi-finished product is defined as an irregular surface "Boundary" and then click on "Calculate" to generate the surfaces (figure 6).

4. Defining the cutting tool

Access the "Create tool" icon and fill in information such as tool name, tool diameter, tool surface length, tool body length, number of teeth, and number assignment in the tool shop (Figure 7).

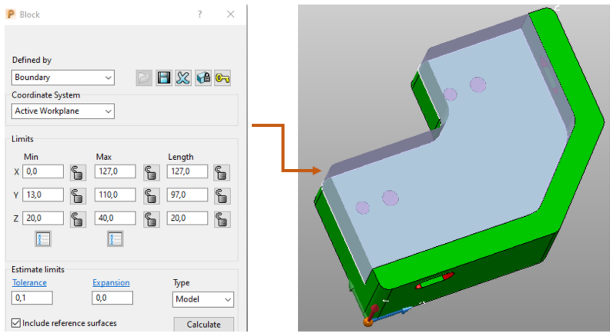


*Fig.6. Definition of the semi-finished product.*

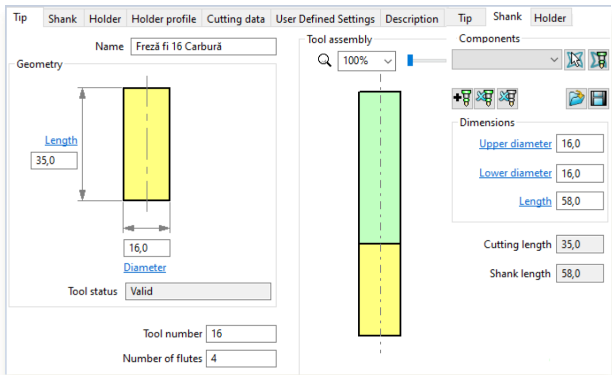


*Fig.7. Defining the cutting tool.*

### *3.2. Milling through the classic strategy*

From the tool manufacturer's catalog we chose the parameters of the cutting process[2,3]: Spindle speed n= 2785 rpm; Table feed Vf= 891 mm/min; Cutting speed Vc= 140 m/min; Feed per tooth fz= 0,08 mm; Axial depth of cut $a_p$= 0,5 mm; Radial depth of cut $a_e$ = 12 mm.
The tool used for this strategy was numbered with 1.

Figure 8 shows the route on which the end mill cutter no. 1 follows it to remove the material. In the case of this strategy, the tool withstands the processing of two parts.

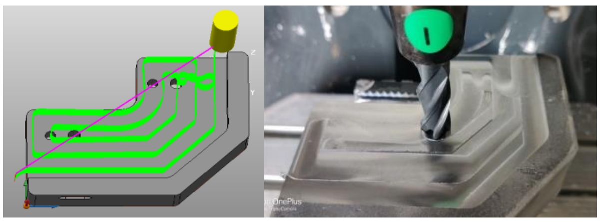

*Fig.8. Processing by the classic milling strategy.*

### *3.3. Vortex milling strategy*

Using an identical tool to the one used in the classic strategy, the batch of parts will be processed by the Vortex strategy. The tool used is defined by 2.

Figure 9 shows the route on which the end mill no. 2 follows it to remove the material. In this case the tool withstands the processing of six parts.

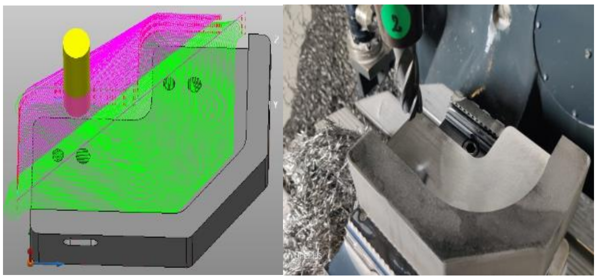

*Fig.9. Processing by Vortex milling strategy.*

## 4. RESULTS AND DISCUSSIONS

### *4.1 Roughness check*

Figure 10 shows the roughness measurement in the case of the two strategies.


*Fig.10. Roughness measurement.*

The roughness (Ra) is measured on the machined parts in seven points using the laboratory TR-200 digital roughness meter. The results from the conventional case processing are presented in Table 1.

*Table 1. Roughness obtained in the case of classical strategy.*

| No. of pieces | Measured values [µm] | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 0.71 | 0.74 | 0.98 | 0.53 | 0.56 | 0.50 | 0.77 |
| 2 | 0.47 | 0.48 | 0.86 | 0.87 | 0.55 | 0.61 | 0.73 |

Mediate (Ra)= 0.66 µm

The results obtained in the case of processing through the Vortex strategy are presented in Table 2.

*Table 2. Roughness obtained in the case of Vortex strategy.*

| No. of pieces | Measured values [µm] | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 0.40 | 0.36 | 0.42 | 0.38 | 0.43 | 0.33 | 0.47 |
| 2 | 0.24 | 0.60 | 0.42 | 0.33 | 0.47 | 0.53 | 0.38 |
| 3 | 0.37 | 0.35 | 0.43 | 0.45 | 0.27 | 0.38 | 0.41 |
| 4 | 0.27 | 0.48 | 0.49 | 0.47 | 0.40 | 0.43 | 0.50 |
| 5 | 0.35 | 0.44 | 0.42 | 0.37 | 0.41 | 0.39 | 0.41 |
| 6 | 0.37 | 0.46 | 0.33 | 0.42 | 0.40 | 0.44 | 0.31 |

Mediate (Ra) = 0.40 µm

Better roughness is obtained in the case of processing through the Vortex strategy.

### *4.2 Checking tool wear*

**The classic strategy**

In order to check the wear of the tools used in the two strategies, the behavior of the cutter during machining, the loading of the machine, the sound produced by the milling cutter and its visual verification after each machined part were followed. Thus, for the classic milling strategy, the machine load was 1-2% at the first processed part and 6-7% on the second part (figure 11, a). At the first mark after processing, the visual inspection did not detect tool wear. After processing the part with no. 2 significant signs of wear appeared at the corners of the cutter (figure 11, b) and the sound produced was very strong.

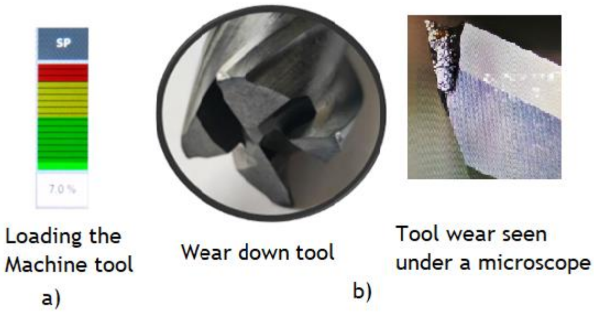


*Fig. 11. Loading the Machine tool end Wear down tool (strategy Classic).*

Based on these results, we found that the maximum wear limits of the cutter have been reached and it is no longer possible to continue processing other parts with it.

**Vortex strategy**

For the VORTEX milling strategy, the parameters followed were the same as in the case of the classic milling strategy. For the parts processed with this strategy, the load of the machine was 19-20%. (Figure 12, a). From the visual inspections after each machined part, on the sixth piece there were signs of wear on the active surface of the cutter and a detachment of a piece of material from one of the teeth of the cutter (figure 12, b), forcing the processing to stop.

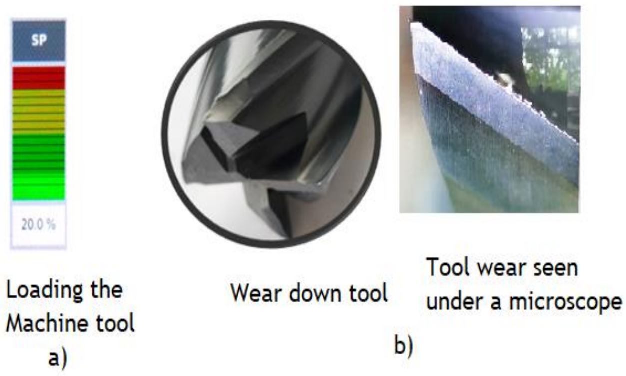


*Fig.12. Loading the Machine tool end Wear down tool (strategy Vortex).*

### *4.3 Analysis of tool life*

The tool life is shown in Table 3.

*Table 3. Tools life*

| **Tools life** | | |
|---|---|---|
| ***Strategy used*** | ***Classic*** | ***Vortex*** |
| Average duration | 1h 37' | 1h 11' |
| Time/ 1 piece | 0:41:14 | 0:11:10 |
| Maximum number of parts | 2 pieces | 6 pieces |

Table 4. shows: the processing time of a part, the price of a tool, the hourly processing rate on a 5-axis CNC machine, the cost of a part without the price of the cutting tool, the costs for processing one or two parts.

*Table 4. Cost/time ratio* for the two processing strategies.*

| **Strategy** | **Classic** | **Vortex** |
|---|---|---|
| Processing time/piece | 00:41:14 | 00:11:10 |
| Tool price | 144.30 | 144.3 |
| Cost CNC 5 axis | 45 | 45 |
| Part processing cost(without tool) | 30.86 | 8.32 |
| Total cost/1 piece | 175.16 | 152.66 |
| Total cost/ 2 pieces | 206.01 | 160.95 |

** The costs are in Euros.*

Following this report, a difference of costs can be observed depending on the chosen processing strategy. To clearly see the differences of costs between the two strategies, Table 5 shows the costs for six identical parts, because this number is the maximum number of parts that can be processed with a single tool using the Vortex milling strategy.

*Table 5. Costs* for processing parts according to the chosen milling strategy.*

| **Number of pieces** | **Strategy classic** | **Strategy Vortex** |
|---|---|---|
| 1 | 175.16 | 152,66 |
| 2 | 206.01 | 160.95 |
| 3 | 381.16 | 169.27 |
| 4 | 412.02 | 177.59 |
| 5 | 586.18 | 185.91 |
| 6 | 618.04 | 194.23 |

** The costs are in Euros.*

## 5. CONCLUSIONS

The results obtained are the basis for choosing the optimal processing option, taking into account the processing time and costs. In order to process a batch of six pieces with the classic milling strategy we need 3 milling cutters compared to the Vortex type milling strategy for which only one milling cutter is enough. The difference of costs between the two milling strategies is 423.78 Euro.

The roughness of the surface processed with the Vortex milling strategy is better than the classic milling strategy because the average Ra = 0.403µm in the case of the Vortex milling strategy is lower than the classic milling strategy where Ra = 0.658 µm. This roughness difference is given by the radial cutting depth (ae) between the two milling strategies.

REFERENCES

1. Cotetiu, I.R., Moldovan, A., Alexandrescu, I.M., Nasui, V.,( 2019), Optimal design through the utility function parameterization method on electromechanical actuators, Materials Science and Engineering 514 – 012017.
2. ***https://www.hoffmann-group.com
3. ***https://www.sandvik.coromant.com

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