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Researches regarding the reducing of burr size by optimising the cutting parameters on a CNC milling machine

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Abstract. This paper presents some experimental researches regarding burrs dimensions reduction that appear after the milling process together with an approach to reduce or eliminate the burrs resulted after this process. In order to reduce burrs dimensions, the milling process was executed with different cutting parameters and strategies then the results were evaluated.

1 Introduction

Milling is a machining operation performed with a rotating, multi-edge cutting tool. The tool performs programmed feed movements in almost any direction for removing material from a workpiece, achieving a prismatic, polyhedrical or free-form shape [1]. Milling is much more versatile than drilling, turning, slotting or any other material removal operation. Each of the milling tool cutting edges removes a small amount of material, with a limited engagement into the raw piece, generally producing small chips which it is easy to remove from the cutting area. As in all machining processes, the harder the material, the more difficult it is to remove by cutting [2].

A literature survey has shown that many researches were focused upon improving the accuracy of machined parts, by altering the control parameters of the CNC milling machines using comprehensive modeling and simulation approaches [3, 4], or even virtual machine-tools [5] or by using new solutions for actuating the main drives or the feed drives [6], but only few papers had tackled the problem of reducing the burr size [7].

Depending on the destination of parts, burrs can significantly affect the overall functioning of an assembly. There is always a danger that a burr to be detachable and come off affecting the operation and cleanliness, where a cleaner working environment frees of impurities is necessary and sometimes imperative.

2 Experimental researches

The experimental researches were carried out on a CNC cutting machine Chiron FZ12 S equipped with Sinumerik 840D CNC control.

Some of the CNC machine characteristics are shown in Table 1.

The parts used for the experiment were cylinder shaped of 20 mm in diameter of alloy steel 16MnCr5 (1.7131). The dimensions which must result after milling are shown in Figure 1 represented by the thick black contour.

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Table 1. CNC machine characteristics.

Parameter	Unit	Value
Maximum path [X–Y–Z]	[mm]	550–400–420
Maximum electrical power	[kW]	40
Maximum spindle speed	[rpm]	40000
Chip-to-chip time starting from	[s]	2.2
Maximum axis acceleration [X–Y–Z]	[g]	1-1.5-2
Rapid feed as fast as	[m/min]	75
Max. number of tools	-	206
Tool taper	-	HSK 40 / HSK 50 / HSK 63
Maximum tool weight	[kg]	[5.0]
Maximum tool diameter	[mm]	125
Maximum tool length	[mm]	250

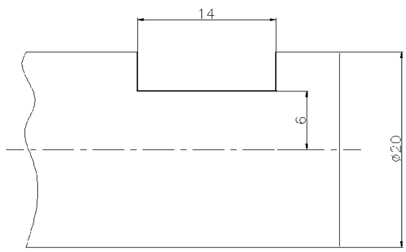

Fig.1 Dimensions after milling.

For the experiment, two types of tools were used shown in Figures 2 and 3 respectively. First was a 4 flute Guhring milling cutter and the second a 6 flute Sandvik milling cutter.

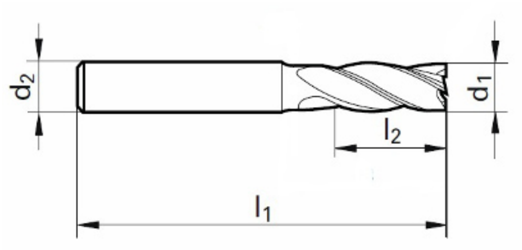

Fig. 2. Guhring cutter 4 flute.

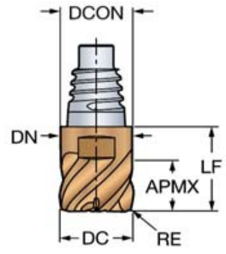

Fig. 3. Sandvik cutter 6 flute.

Both tools characteristics are shown in Table 2 and 3 respectively.

Table 2. Guhring cutter characteristics.

Parameter	Unit	Value
Total length l1	[mm]	73
Depth of cut maximum l2	[mm]	16
Cutting diameter d1	[mm]	12
Shank diameter d2	[mm]	12
Corner chamfer	[mm]	0.15
Flute helix angle	[deg]	30

Table 3. Sandvik cutter characteristics.

Parameter	**Unit**	**Value**
Connection diameter DCON	[mm]	12.3
Neck Diameter DN	[mm]	12.3
Cutting diameter DC	[mm]	12.7
Depth of cut maximum APMX	[mm]	7
Flute helix angle	[deg]	50
Functional length LF	[mm]	14.6
Corner chamfer RE	[mm]	0.38

For the experiment, climb milling was used because according to the specialty literature the surface finish is better by working with this strategy.

The first tool used for the experiment was Guhring cutter 4 teeth.

The milling strategy was established as follows: one pass roughing and two passes finishing. Material left on bottom (a_p) and sides (a_e) was 1 mm for finishing.

The cutting parameters are shown in Table 4.

Figures 4 and 5 respectively shows the burrs resulted after the test with Guhring cutter 4 flute 30^o helix angle. As seen, it is almost impossible to have a precise measure of the burrs.

Table 4. Cutting parameters Guhring cutter, one pass roughing, two passes finishing.

Parameter	Roughing	Finishing	Unit
Spindle speed S	2000	3000	[rpm]
Feed per turn f	0.2	0.25	[mm/rot]
Feed per tooth fz	0.05	0.0625	[mm]
Axial depth of cut a_p	4	1	[mm]
Radial depth of cut a_e	12	1	[mm]
Cutting speed vf	400	750	[mm/min]

As shown in Table 4, the cutting parameters for finishing were increased because after roughing there is much less material to remove and the cutting forces are reduced.

Fig. 4. Burrs resulted after one pass roughing and two passes finishing (a_p=1; a_e=1) 4 flute 30 ^{o} helix angle.

Fig. 5. Burrs resulted after one pass roughing and two passes finishing (a_p=1; a_e=1) 4 flute 30^o helix angle.

Considering specialty literature, the ae and ap are influencing the surface quality and burrs dimensions. Therefore in order to reduce the burrs dimensions, the milling strategy was changed to two passes roughing and two passes finishing. Considering the influencing factors, the material left for finishing was a_p = a_e=0.2. The speed and feed of the tool were not changed. Figure 6 shows the results after changing the axial (a_p) and radial (a_e) depth of cut.

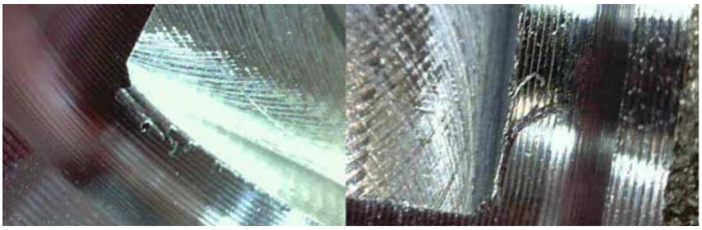

Fig. 6. Burrs resulted after two passes roughing and two passes finishing (a_p=0.2; a_e=0.2) 4 flute 30° helix angle.

As seen, by reducing the a_e and a_p for finishing, the burrs dimensions are reduced. In Figure 7 are shown the burrs dimensions resulted after working with a_e =0.2 and a_p =0.2, where it can be seen that the root of the burr x and the height z can be measured now.

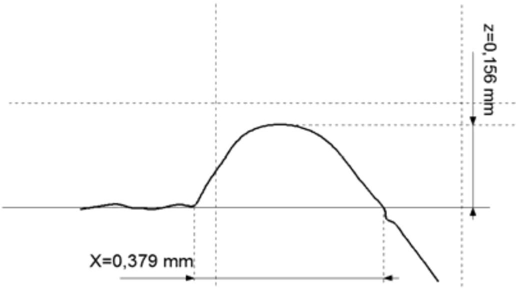

Fig. 7. Burrs dimensions after two passes roughing and two passes finishing (a_p=0.2; a_e=0.2) 4 flute 30° helix angle.

In the next stage of the experiment, Sandvik cutter 6 flute 50° helix angle was tested.

First, the milling strategy was established as follows: one pass roughing and two passes finishing. Because of the 6 tooth milling cutter, all the cutting parameters were increased for this tool. Increasing the cutting parameters also allows a reduced cycle time, which is very important in a serial production resulting more parts in a shorter time. The cutting parameters for this strategy are shown in Table 5.

Table 5. Cutting parameters Sandvik cutter, one pass roughing, two passes finishing.

Parameter	Roughing	Finishing	Unit
Spindle speed S	3000	3500	[rpm]
Feed per turn f	0.25	0.3	[mm/rot]
Feed per tooth fz	0.041	0.05	[mm]
Axial depth of cut a_p	4	0.65	[mm]
Radial depth of cut a_e	12.7	0.65	[mm]
Cutting speed vf	750	1050	[mm/min]

Figure 8 and 9 respectively shows the burrs resulted after the test with Sandvik cutter 6 flute 50° helix angles. Figure 9 shows the measurements of the burr's root x and height z.

As can be seen, burrs resulted are smaller compared to the burrs resulted by using the first cutter.

In order to further reduce the burrs dimensions, the cutting strategy was changed again by working with two passes roughing and two passes finishing, reducing the material left for finishing to a_e=a_p=0.2 mm.

Fig. 8. Burrs resulted after one pass roughing and two passes finishing (a_p=0.65; a_e=0.65)
6 flute 50° helix angle

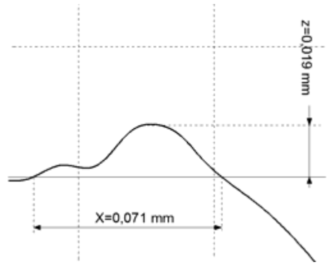

Fig. 9. Burrs dimensions after one pass roughing and two passes finishing (a_p=0.65; a_e=0.65)
6 flute 50° helix angle

Cutting parameters for this strategy are shown in Table 6.

Table 6. Cutting parameters Sandvik cutter, two passes roughing, two passes finishing.

Parameter	Roughing	Finishing	Unit
Spindle speed S	3000	3500	[rpm]
Feed per turn f	0.25	0.3	[mm/rot]
Feed per tooth fz	0.041	0.05	[mm]
Axial depth of cut a_p	4	0.2	[mm]
Radial depth of cut a_e	12.7	0.2	[mm]
Cutting speed vf	750	1050	[mm/min]

Burrs dimensions resulted after working with this strategy is shown in Figure 10.

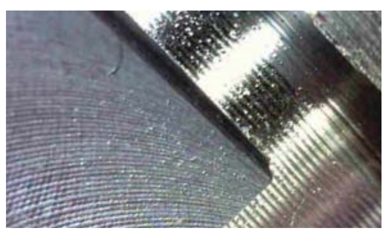

Fig. 10. Burrs dimensions after two passes roughing and two passes finishing (a_p=0.2; a_e=0.2)
6 flute 50° helix angle.

As can be seen in Figure 10, the burrs are much smaller and can be removed if necessary by a brushing operation.

To further reduce or eliminate the burrs, the cutting parameters were changed as shown in Table 7.

Table 7. Cutting parameters Sandvik cutter, two passes roughing, two passes finishing.

Parameter	Roughing	Finishing	Unit
Spindle speed S	3000	3800	[rpm]
Feed per turn f	0.25	0.25	[mm/rot]
Feed per tooth fz	0.041	0.041	[mm]
Axial depth of cut a_p	4	0.2	[mm]
Radial depth of cut a_e	12.7	0.2	[mm]
Cutting speed vf	750	950	[mm/min]

The results after milling with these parameters for finishing pass are shown in Figures 11 and 12. In Figure 11 it can be seen that the root x and height z of the burrs are greatly

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reduced after optimizing the cutting parameters. Figure 12 shows that no burr was detected during measuring, after implementing the parameters shown in Table 7.

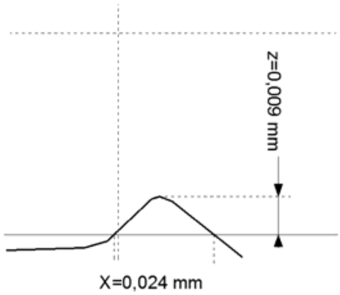

Fig. 11. Without burrs resulted after two passes roughing and two passes finishing (a_p= a_e=0.2 mm) and after changing the parameters for finishing
6 flute 50° helix angle.

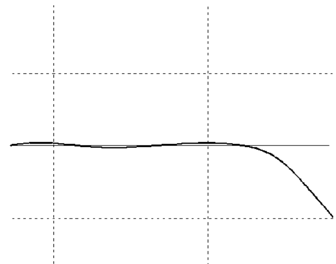

Fig. 12. Without burrs resulted after two passes roughing and two passes finishing (a_p= a_e=0.2 mm) and after changing the parameters for finishing
6 flute 50° helix angle.

As seen above, the burrs disappeared by cutting with these parameters using 6 flute cutter.

3 Conclusions

The experiment shows that the cutting parameters such as speed and feed have a major influence on the burrs dimensions, which is why these parameters must be chosen depending on the application and maintaining a balance between cycle time and tool capabilities. The material left for finishing pass after roughing also influences the size of burrs. Also, regarding the cutting tool, the experiment shows that choosing a tool with more teeth and a greater helix angle help to significantly reduce the burrs dimensions. Considering that in order to reduce the burrs dimensions were needed to increase the speed and to reduce the feed, further researches can take place on the cutting parameters influence on the tool durability.

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