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Edge Deburring Using Ceramic Brushes

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The article presents issues of the deburring process. The influence of individual parameters of deburring with ceramic brushes on the roughness and rounding of deburred edge has been shown.

Keywords: deburring, burrs, brushes, edge rounding, PA9.

1. Introduction

In the process of machining multiple negative phenomena appear. One of them is the formation of a burr in the form of plastically deformed material at the edge of the workpiece. This phenomenon occurs in practically all machining processes while the tool is leaving the cutting zone [1].

In some cases occurring of burr worsens only aesthetic value of the element not referring in any way to the deterioration of its features. However, more and more often very strict requirements are also made towards the edges of elements causing multiple problems such as making the assembly process more difficult or impossible, faster using up of the parts and cutting tools, as well as deranging fluids and gases flow or the cuts of the workers. [2, 3].

Formation of burr during machining process is an extremely complex, multistep phenomenon. Large amount of factors mutually influencing each other effectively makes it difficult to thoroughly examine the problem and choose the appropriate deburring technology [4, 5, 6]. Enormous need for effective and cheap ways of removing burrs led to the development of many methods solving the problem.

The increasing automation displaces manual deburring for faster (and thus usually cheaper) methods. One of them is deburring with ceramic brushes, examined in this paper.

2. Test stand and methodology

The samples used in the research (Fig. 1) have been prepared on the manual milling machine JAFO FWD32J. For this purpose Ø 12 mm diameter four-blade cylindrical milling cutter made of HSS was used. Cutting speed during the cut was v_c = 88 m/min, feed rate f = 28 mm/min while the cut layer thickness a_p = 5 mm. The samples were made of aluminum alloy PA9, which is characterized by a very good durability, thermal conductivity and resistance to corrosion. It is classified in the first group in terms of machinability (very good machinability and polishing behavior).

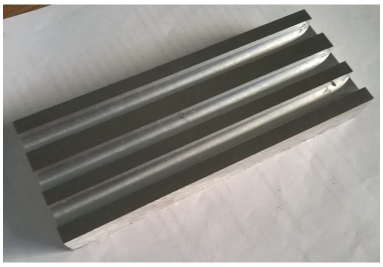

Figure 1 Aluminium sample

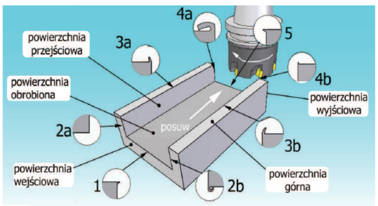

Figure 2 The types of burrs occurring during the milling [7 for 8]

The samples prepared in this way were examined with profilographometer TAYLOR HOBSON FORM TALYSURF 120L (Fig. 3.) for rounding and roughness of the upper edges of the grooves. There has been used the same indicator for the edges as presented in this work [7 for 8] (Fig. 2).

The next stage of the study was taking photos of raw edges with use of a microscope ZEISS SteREO DISCOVER (Fig. 4).

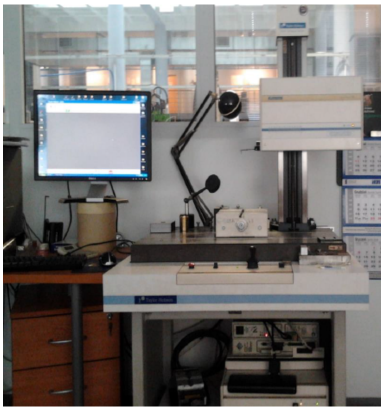

Figure 3 Profilographometer TAYLOR HOBSON FORM TALYSURF 120L

Figure 4 Microscope ZEISS SteREO DISCOVER

In Fig. 5. the edge after milling is shown. You can notice large amount of burrs left after the process. Analyzing the results from Table 1 you can note that the process of milling a groove with end mill introduces negligible edge rounding, however the value of the parameter Rt is relatively high. What is also significant both the radius of the curve and the value of the maximum height of the roughness are definitely greater for edge of 3a.

The milling machine JAFO FWD32J was used for brushing the edge. It was necessary to mount manual grinder METABO GE 950 G to it, due to too small range of rotational speed of the main spindle. For this purpose specially designed handle was used (Fig. 6).

Table 1 The edge radius and the value of the edge Rt parameter before brushing

		Edge 3a	Edge 3b
The edge radius	[mm]	0,061	0,016
Rt	[m]	12,948	9,235

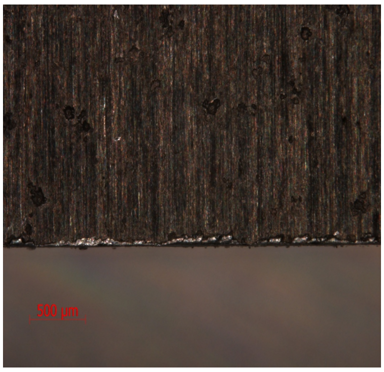

Figure 5 The appearance of the edge 3B after milling, zoom ×40

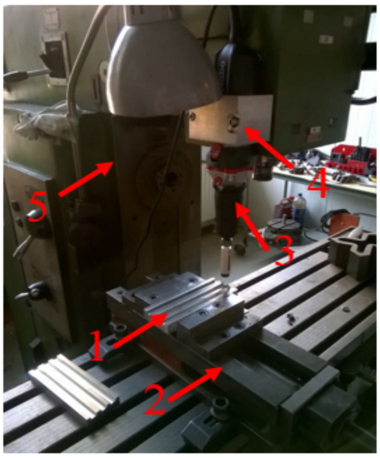

Figure 6 Test stand (1- sample, 2- bench vice, 3- grindstone with ceramic brush, 4- handle, 5- milling machine)

During the brushing combination of 27 technological parameters shown in Tab. 2 was used. The width of grooves enabled to brush both upper edges during one use of the tool.

After brushing samples were examined again with profilographometer and microscope.

Table 2 Combination of technological parameters used during brushing

	Rotational speed [min^{-1}]	Feed rate [mm/min]	a_p [mm]
1.	2500	710	0,25
2.		900	
3.		1120	
4.	4000	710	
5.		900	
6.		1120	
7.	5500	710	
8.		900	
9.		1120	
10.	2500	710	0,5
11.		900	
12.		1120	
13.	4000	710	
14.		900	
15.		1120	
16.	5500	710	
17.		900	
18.		1120	
19.	2500	710	1
20.		900	
21.		1120	
22.	4000	710	
23.		900	
24.		1120	
25.	5500	710	
26.		900	
27.		1120	

2.1. *Characteristics of the brushes used in the process*

XEBEC Ceramic brushes with catalogue number A11-CB15M were used during the tests (Fig. 7–8).

These brushes are made of ceramics Al_2O_3 which provides self-sharpening properties to fibers. Single fiber consists of approximately 1000 fibers with a diameter of a few micrometers. The tools design enables to use them both on machining centers, robots, drills and grinders.

3. Tests results

Due to the lack of standardized criteria for defining the roughness it was evaluated on the basis of parameter Rt. During the edge examination with profilographometer a Gaussian filter was used and the values of the Cut-off (Lc) and the Cut-off (Ls) parameters were accordingly 0.8 and 0.0025 mm.

The results obtained of the fillet and the Rt parameter of grooves edge are the average of three measurements.

Figure 7 Brush A11-CB15M

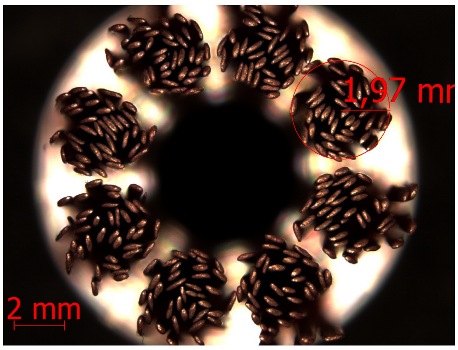

Figure 8 The view of brush A11-CB15M face

3.1. *The impact of the brushing on the fillet of the grooves upper edges*

Tab. 3 shows the results of the measurements of the groove edge fillet after the brushing. Reading them, you can see that in the case of both upper edges their maximum fillet takes place during processing with the use of an identical set of technological parameters (set number 16) and is accordingly 0.146 and 0.117 mm. Minimum value of this parameter for the edge 3a took place during the processing with set 2 (0.054 mm) and for edge 3b with set 10 (0.025 mm). It should be noted that the use of ceramic brushes in every case increased the edge fillet (in the most extreme case of as many as 24 times).

Table 3 The results of measurements of groove edge fillet after brushing

	Rotational speed [min^{-1}]	Feed rate [mm/min]	a_p [mm]	Edge 3a [mm]	Edge 3b [mm]
1.	2500	710	0,25	0,060	0,034
2.		900		0,054	0,040
3.		1120		0,080	0,055
4.	4000	710		0,065	0,060
5.		900		0,067	0,053
6.		1120		0,075	0,051
7.	5500	710		0,067	0,057
8.		900		0,065	0,064
9.		1120		0,077	0,052
10.	2500	710	0,5	0,122	0,025
11.		900		0,109	0,051
12.		1120		0,092	0,035
13.	4000	710		0,111	0,081
14.		900		0,094	0,068
15.		1120		0,080	0,057
16.	5500	710		0,146	0,117
17.		900		0,138	0,111
18.		1120		0,122	0,099
19.	2500	710	1	0,061	0,029
20.		900		0,065	0,037
21.		1120		0,078	0,043
22.	4000	710		0,107	0,066
23.		900		0,066	0,098
24.		1120		0,074	0,079
25.	5500	710		0,120	0,106
26.		900		0,114	0,102
27.		1120		0,128	0,094

In the further part the influence of selected parameters on the fillet of the upper edges is presented in the form of graphs.

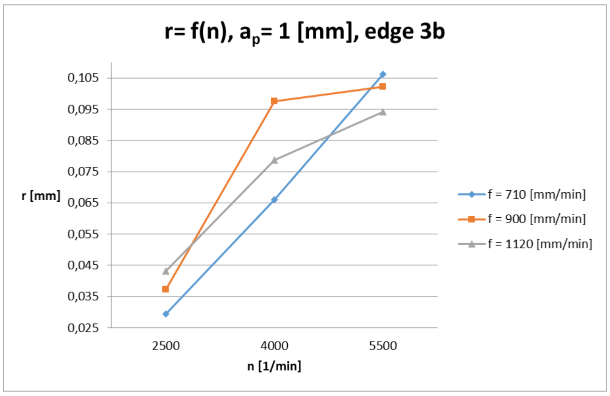

Figure 9 The impact of rotational speed on the groove edge fillet at a_p= 1 mm, edge 3b

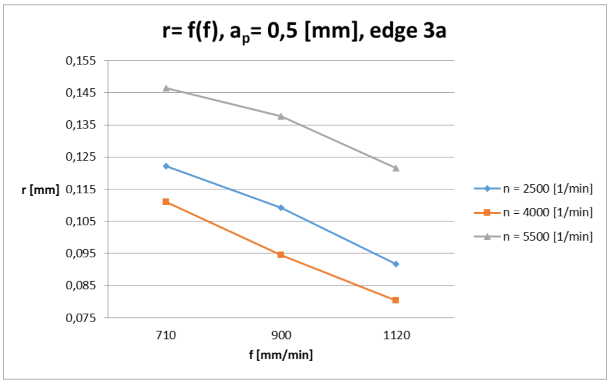

Figure 10 The impact of feed speed on the groove edge fillet at a_p= 0,5 mm, edge 3a

Analyzing the results presented above, you can notice the following impact of individual technological parameters on the value of the groove edge fillet:
– Rotational speed (n)- you may notice strong correlation between rotational speed and the size of edge fillet. Increasing the tool rotation leads to a significant increase in the measured parameter. It should be noted that this relationship works for both tested edges.
– Feed speed (f)- with exception of a few cases you can certainly conclude that increasing the feed speed affects the reduction of groove edge fillet. Even though the manufacturer recommends a higher (even twice) values of feed speed, in the analyzed range you can still note strong impact of this parameter and a significant change of edge fillet. As suggested by the results the feed is very important parameter when designing technological process using abrasive brushes.

– Infeed (a_p) – the effect of infeed is not unambiguous. In the case of edge 3a, for rotational speed n = 5500 min^{-1} you may notice an increase in edge fillet with increasing brush pressure. In the case of 3b edge it is difficult to find any dependencies. You can ascertain, that there is a limit of feed and rotational speed, and after crossing it pressure influence will be negligible.
At Fig. 11-12 the appearance of selected edges 3a and 3b is presented. Comparing them to Fig.5 you may notice complete removal of burr created during the milling as well as formation of characteristic mark left by working ceramic brush.

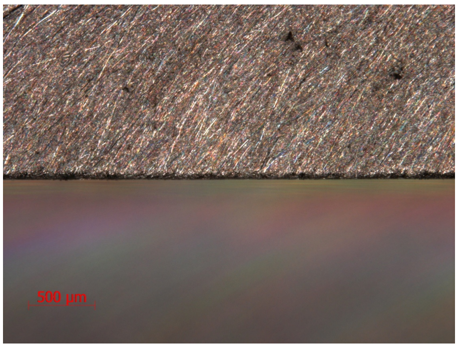

Figure 11 The appearance of edge 3b after brushing, edge fillet 0,117 mm, zoom ×40

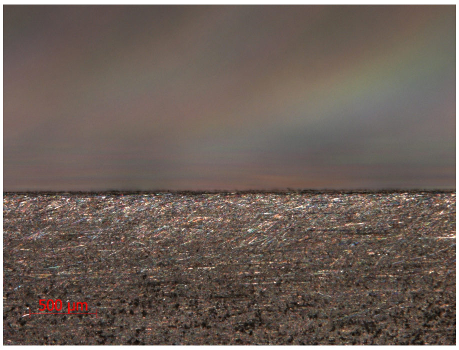

Figure 12 The appearance of edge 3a after brushing, edge fillet 0,054 mm, zoom ×40

3.2. *Impact of brushing on roughness of grooves upper edges*

Tab. 4 summarizes the results of the parameter Rt measurements after the brushing. By comparing the values of this parameter for both edges with the results of their fillets you may notice that also in this case, there are significant differences between the edges 3a and 3b. Extreme values of roughness have appeared every time during processing with other technological parameters. Referring to the value of the parameter Rt (samples before brushing) it should be noted that depending on the combination of technological parameters used in the process, the value of the Rt increased or decreased. In conclusion, there is an optimal set of technological parameters, which use will enable to obtain the possibly smallest roughness of brushed edges.

Table 4 The results of the measurements of Rt parameter after brushing

	Rotational speed [min^{-1}]	Feed rate [mm/min]	ap [mm]	Edge 3a [mm]	Edge 3b [mm]
1.	2500	710	0,25	8,257	9,312
2.		900		9,975	8,963
3.		1120		13,011	8,165
4.	4000	710		4,062	8,098
5.		900		7,833	7,698
6.		1120		10,617	7,451
7.	5500	710		4,075	7,379
8.		900		6,223	6,929
9.		1120		9,549	6,126
10.	2500	710	0,5	3,821	6,818
11.		900		4,349	5,003
12.		1120		6,917	4,496
13.	4000	710		5,604	8,171
14.		900		7,244	9,342
15.		1120		8,656	10,106
16.	5500	710		4,560	6,433
17.		900		8,832	5,223
18.		1120		13,205	4,753
19.	2500	710	1	4,007	5,379
20.		900		6,275	4,889
21.		1120		8,549	4,544
22.	4000	710		4,340	6,595
23.		900		5,845	5,225
24.		1120		9,674	4,884
25.	5500	710		6,053	11,787
26.		900		9,332	9,984
27.		1120		14,278	9,543

Interpreting drawn up charts of the influence of individual technological parameters on the value of the edge Rt parameter after brushing you can come to following conclusions:

– Rotational speed (n)- in every case, the increase in rotational speed affected the increase in roughness of the edge. It is worth noticing that in the case of 3a edge, the greatest value of the Rt parameter was reached during processing at the feed

speed of f = 1120 mm/min, then 900 and 710 mm/min. In the case of 3b edge, the situation is exactly the opposite.
– Feed speed (f) -the impact of the feed speed on the value of the Rt parameter is completely different for both tested edges. In the case of edge 3a its growth leads to the intensive growth of roughness, while the situation with the edge of the 3b is completely opposite. In both cases, however, the smallest value of the Rt parameter have been obtained during the processing at the rotational speed of 5500 min^{-1}.
– Infeed (a_p) – also in this case the effect of infeed is not unambiguous, and stating any dependency is at the moment impossible. To finally determine the role of this parameter it is recommended to carry out further research.

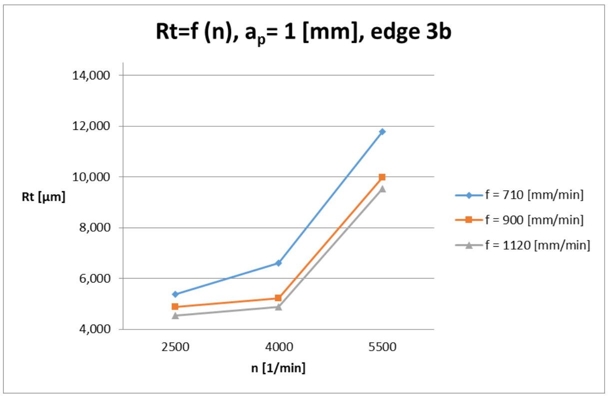

Figure 13 The impact of rotational speed on value of 3b edge Rt parameter with infeed a_p= 1 mm

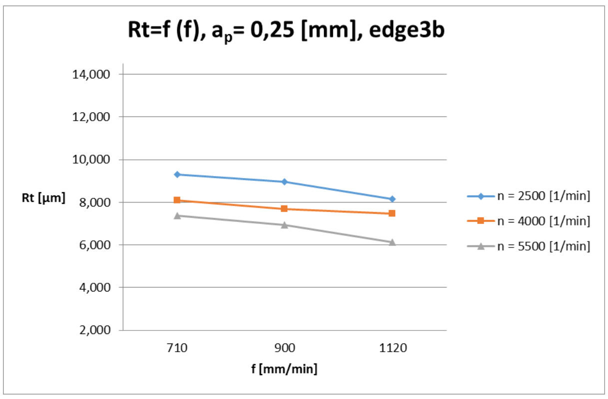

Figure 14 The impact of feed speed on value of 3b edge Rt parameter with infeed a_p= 0,25

In the further part of the work, photos of the upper edges of the grooves obtained using a microscope ZEISS SteREO DISCOVER are presented. These pictures show the edges characterizing with extreme values of the Rt parameter. Particular attention should be paid to Fig. 16-17. They present loss of material that occur along the entire length of the groove edge.

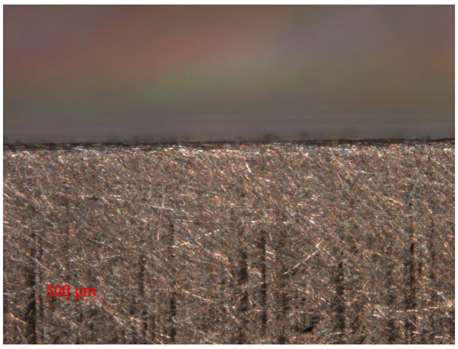

Figure 15 The appearance of 3a edge after brushing, Rt= 3,821 m, zoom ×40

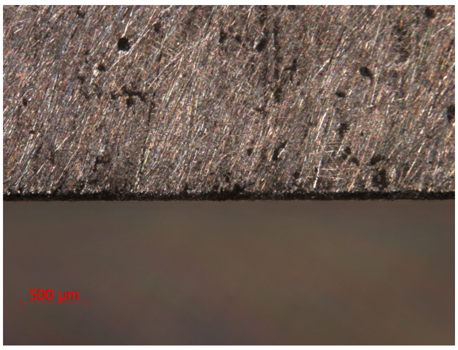

Figure 16 The appearance of 3b edge after brushing, Rt= 11,787 m, zoom ×40

4. The summary and conclusions

The above studies have proven the brush capability to remove the burr created during milling and the analysis of the experimental research results enables to formulate the following conclusions and observations:
– The experimental research has shown the impact of individual technological parameters (rotational speed of the tool, feed speed and the pressure of the brush on the sample) on the shape and size of the cut and grooves edges roughness,
– Brush infeed is the parameter, which influence on tested values is not unambiguous and requires further thorough analysis,

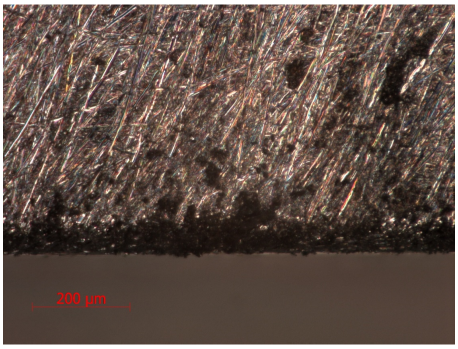

Figure 17 The appearance of 3b edge after brushing, Rt= 11,787 m, zoom ×100

– Strong correlation between the rotational and feed speed as well as value of Rt parameter evaluated on bisector of the edge has been noticed in the range of applied processing parameters. In every analyzed case the increase of rotational speed caused the increase of both tested parameters. The increase of feed speed always resulted in the decrease of both edges fillet, however its impact on Rt parameter was different. In 3a edge case the increase of feed speed led to the increase of maximum value of roughness, when in 3b edge case the influence of feed speed was exactly the opposite.
– For both edges the values of fillet and roughness for grooves upper edges after the grating differ significantly. The explanation of this fact should be searched in the kinamatics of the processing. The edge 3a was brushed the way forward, while 3b in a counter. It resulted in achieving lower values of edges fillet and their roughness in case of 3a edge.
– Deburring with ceramic brushes introduces significant edge fillet and changes its roughness. In the most extreme case brushing resulted in 24 times increase of the edge fillet. Whereas the roughness is the parameter, which increased or decreased depending on applied set of technological parameters.
– The method of evaluation of fillet and Rt parameter enabled to estimate the impact of brushing on tested parameters in repeatable conditions.
– The applied experimental brushing method can be used for machining tests of different materials.

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