INFLUENCE OF CERAMIC TOOL PROCESSING PARAMETERS ON THE STATE OF NC6 STEEL SURFACE

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Abstract

The article presents the characteristics of ceramic tools designed to improve the condition of the surface layer of workpieces. After milling or turning, the surface layer of the workpiece often has several disadvantages, such as burrs or uneven roughness. Brushed ceramic tools allow the surface layer to be improved as another technological step in the entire manufacturing process. The presented tests of the geometrical surface structure were made for NC6 tool steel for cold work. An analysis of the impact of brushing technological parameters on the height of unevenness and visual features of the machined surface was carried out.

Keywords: Brush deburring, ceramic tools, finishing processes, surface quality

1. INTRODUCTION

Along with the increase in the automation and mechanization of production processes, new types of finishing treatments were developed, allowing to accelerate work while maintaining full parameterization of production processes. Unfortunately, many types of finishing treatments engage the use of additional machines or human resources. Deburring or improvement of surface roughness can be done by mechanical, thermal or electrical methods, but unfortunately not all methods can be used alternately due to changes in the state of the surface layer of the workpiece after applying the selected methods. In mechanical methods, an example of tools used in finishing can be brushes with ceramic fibers for deburring, which can be successfully used on machines performing previous machining tasks. Ceramic brushes come in many varieties and types, depending on the place of application and workpiece material [1,2].

The quality of machined surfaces depends on factors such as the properties of the workpiece, cutting parameters, cutting edge geometry and wear as well as the stiffness of the machine tool-holder-workpiece-tool system. These factors affect the amount of micro-evenness of the surface layer of the workpiece by means friction [3,4]. Micro-unevenness on the surface of an object arising during use and in the manufacturing process itself is referred to as the directivity of the geometric structure of the surface. There are different types of directionality shown in **Figure 1** [5].

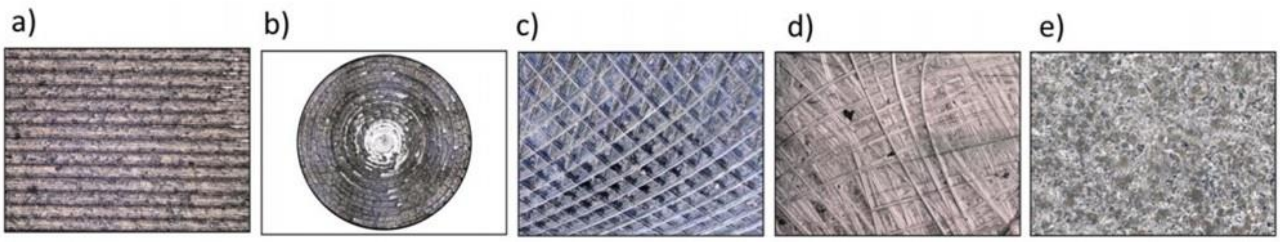


Figure 1 Directivity of the geometric structure of selected surfaces: a) parallel, b) concentric, c) crossed, d) omnidirectional disordered, e) point [10]

The assessment of the geometrical structure is made, based on measurements of surface roughness, waviness or using organoleptic methods. Therefore, all types of finishing operations also affect the final surface roughness.

Finishing can include brushing, in which the removal of the workpiece occurs as a result of the impact of the abrasive tool on the surface of the object, the tool being a brush that performs rotary and sliding movement.

The fiber impact zone on the treated surface can be divided into three parts, which are the areas of initial, advanced and final contact. In the first of them, the contact of the fiber with the object is initiated and cutting begins, which is accompanied by the appearance of forces resulting from the impact of the fiber on the surface, their value being constant. In the next phase of the process, a further increase in forces is observed until they reach their maximum value at the point being the center of the fiber contact zone with the surface. In this stage, the fiber moves along the material leaving a trace of processing. In turn, in the area of final contact, the fiber exits the machining zone and the gradual decay of forces, whose value is a function of the rotational speed of the tool, i.e. the forces increase with increasing speed and decrease as this speed decreases. The effect of exerting pressure is changing the properties of the surface layer and introducing small compressive stresses into it. In addition to pressure, the factors determining the effects of brushing are also the properties of the workpiece, rotational speed, feed and tool diameter, fiber characteristics and machining direction or the number of repetitions of machining cycles.

There are many types of brushing tools that are divided in terms of: removing or adding material [6], tool geometry and the material of which the cutting part is made. There are disc brushes, pot, brush, cylindrical brushes and brushes for cleaning internal surfaces, and each type of brushes can have straight, wavy or braided fibers depending on the needs. In terms of the material from which the brush fibers are made, brushes with metal fibers (usually steel or brass), brushes with plastic fibers and brushes with ceramic fibers, which will be subject to further research, are distinguished. Ceramic brush fibers are made of alumina (Al_2O_3). The fibers are in packages of about 12 individual fibers, and each fiber consists of 500 to 1,000 ceramic microfibers, which do not exceed 10 μm in diameter and are connected by a binder (**Figure 2**). Fibers come in four varieties: pink for plastics, red for soft metals and blue and white for hard materials [7,8].

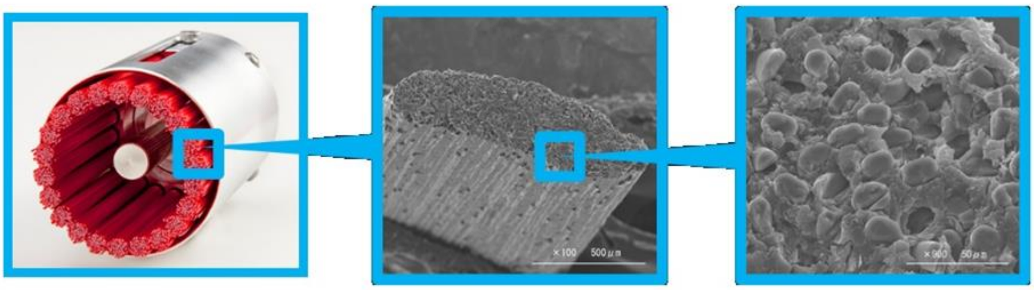


Figure 2 Ceramic fibers of the cup brush under microscopic magnification [9]

2. TEST CONDITIONS

The purpose of the experimental tests was to determine the impact of individual brushing parameters on the quality of the machined surface and to indicate the optimal machining conditions for which it is possible to obtain a surface layer with the lowest possible roughness parameters. The influence of the following factors was considered in the work:

- rotation speed, n [rpm],
- feed speed, v_f [mm/min],
- cutting depth, a_p [mm],
- number of tool passes, I,

- type of brushing tool.

Various combinations of processing parameters were used, using two blue and white pot brushes with ceramic fibers with different abrasive properties (**Figure 3**) together with a compensating handle. After preparation of the samples, including their surface planning, the initial surface roughness was measured. Next, the values of surface roughness parameters after brushing were determined.

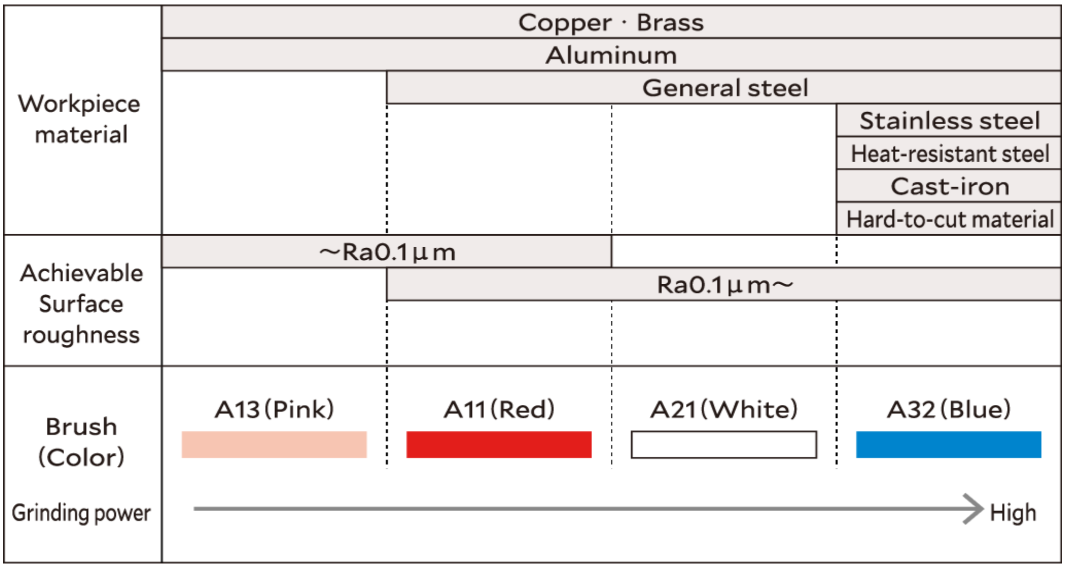


Figure 3 Dependence of the brush color on the type of workpiece and abrasive possibilities [9]

During the tests, samples made of NC6 steel were used, which is classified as alloyed tool steel for cold work.

Both brushing and the preceding surface planning of the samples were carried out on a vertical Cincinnati Milacron Arrow 500 machining center. Surface planning was performed by drilling using a Ø8 mm spherical cutter made of cemented carbide. **Figure 4** shows the sample used in the study.

Figure 4 Face of the sample made of NC6 steel after milling

As part of the experimental tests, the following tests were carried out:

- influence of rotational speed and feed speed on surface roughness (**Table 1, Figure 6**),
- the impact of rotational speed and depth of cut on surface roughness,
- the impact of feed speed and the number of passes on surface roughness,
- the impact of the number of passes on the surface roughness for the blue brush,
- the effect of the number of passes on the surface roughness for a white brush.

In addition, comparative tests of the number of passes and brushing direction were performed for the blue brush (**Table 2, Table 3**) and for the white brush. Below are the results of selected tests and a view of selected samples after treatment.

Table 1 The influence of speed and feed rate to the surface roughness - measurement results

Number of samples	Brush type	Brushing direction	n	v_f	a_p	i	Ra	δRa	Rz	δRz	Rt	δRt
			rpm	mm/min	mm	-	µm					
1p1	Blue	Perpendicular	2.800	1,000	0.5	1	2.42	0.48	8.66	2.04	9.15	1.85
1p2			3.800				2.36	0.54	8.67	2.03	8.82	2.18
1p3			4.800				2.08	0.82	8.55	2.15	9.30	1.70
1p4			5.800				2.05	0.85	8.60	2.10	9.58	1.42
4p1			2.800	2,000			3.17	-0.27	11.94	-1.24	12.42	-1.42
4p2			3.800				2.93	-0.03	11.76	-1.06	12.16	-1.16
4p3			4.800				2.90	0.00	13.12	-2.42	17.24	-6.24
4p4			5.800				2.78	0.12	14.29	-3.59	17.06	-6.06

where:

δRa / δRz / δRt - means the difference between the roughness parameter Ra / Rz / Rt characteristic for the initial surface and the parameter Ra / Rz / Rt measured after brushing; i - the number of tool passes

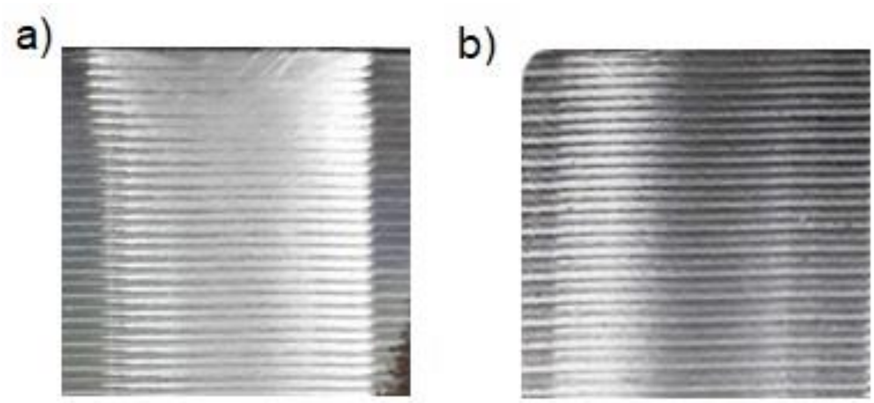
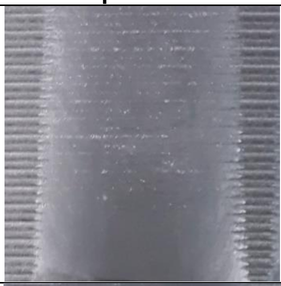
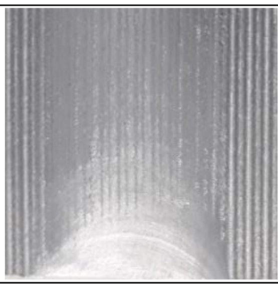
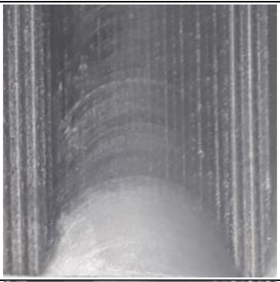
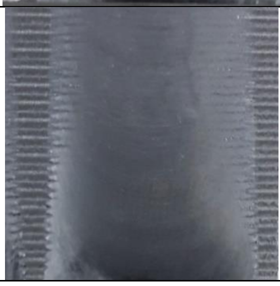
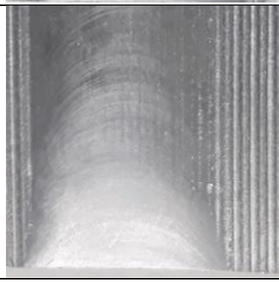


Figure 5 Visual assessment of surface samples after brushing a) view sample 1P4, b) view of the sample 4P1

Table 2 Comparison of surface roughness after blue brush treatment in a perpendicular and parallel direction to the machining marks

Number of samples	Brush type	Brushing direction	n	v_f	a_p	i	Ra	δRa	Rz	δRz	Rt	δRt	l
			rpm	mm/min	mm		µm						mm
7p1	Blue	Perpendicular	5.000	100	0.5	1	0.70	3.24	6.64	11.90	11.76	8.12	4.8
7p2						2	0.59	3.35	4.11	14.43	4.78	15.10	4.8
7p3						3	0.38	3.56	3.66	14.88	5.46	14.42	4.8
9p1		Parallel				1	1.69	2.88	8.66	21.83	10.52	22.02	4.8
10p1						2	0.51	2.99	3.72	13.87	4.12	15.38	4.8
10p2						3	0.29	3.21	2.11	15.48	2.60	16.9	4.8

Table 3 Visual assessment of the surface of samples after brushing with variable number of passes and brushing directions - blue brush

Brush type	Number of passes	Brushing direction	
		Perpendicular	Parallel
Blue	1		
	2		
	3		

3. CONCLUSIONS

Experimental studies have shown that brushing is an effective finishing treatment that can affect the quality of the surface layer of the material being processed. The effects of machining depend on the proper selection of technological parameters such as cutting depth, rotational speed, feed speed and the number of brush passes. The right color of the tool's fibers is also important, as well as the amount of their protrusion from the compensating chuck sleeve.

The influence of brushing technological parameters on surface roughness and visual features was determined:

- rotational speed: it was found that the final values of Ra parameters decreased with increasing brush speed,
- feed speed: an increase in Ra parameters was observed along with an increase in the brush feed speed,
- cutting depth: it has been shown that lowering the cutting depth leads to a decrease in each of the analyzed roughness parameters,
- number of passes: the result of the increase in the number of tool passes was a significant decrease in the roughness parameters Ra, Rz and Rt,
- brushing direction: changing the machining direction from perpendicular to parallel did not affect the significant reduction of roughness parameters of the surfaces tested,
- brush color: the change of the deburring tool from the white to the blue brush has led to a significant improvement in roughness parameters and visual features of the treated surfaces.

REFERENCES

[1] SALACINSKI, T., CHMIELEWSKI, T., WINIARSKI, M., CACKO, R., ŚWIERCZ, R. Roughness of Metal Surface after Finishing Using Ceramic Brush Tools. *Advances in Materials Science.* 2018, vol. 18, issue 1, pp. 20-27. https://doi.org/10.1515/adms-2017-0024.

[2] CHMIELEWSKI, T., HUDYCZ, M., KRAJEWSKI, A., SALACINSKI, T., SKOWRONSKA, B., ŚWIERCZ, R. Structure investigation of titanium metallization coating deposited onto AlN ceramics substrate by means of friction surfacing process. *Coatings.* 2019, vol. 9, issue 12, p. 845. https://doi.org/10.3390/coatings9120845.

[3] IWASZKO J., KUDŁA K., FILA K. Friction stir processing of the AZ91 magnesium alloy with SiC particles. *Archives of Materials Science and Engineering*. 2016, vol. 77, issue 2, pp. 85-92.

[4] SKOWROŃSKA, B., CHMIELEWSKI, T., PACHLA, W., KULCZYK, M., SKIBA, J., PRESZ, W. Friction weldabillity of UFG 316L stainless steel. *Archives of Metallurgy and Materials*. 2019, vol. 64, issue 3, pp. 1051-1058.

[5] KO, S.L., DORNFELD D.A. A study on burr formation mechanism. Transactions of the ASME *Journal of Engineering Materials and Technology.* 1991, vol. 113, issue 1, pp. 75–87.

[6] MATUSZAK, J. *Badania procesu usuwania zadziorów po frezowaniu stopów aluminium i magnezu*. Lublin, 2015. Doctoral thesis, Lublin University of Technology.

[7] SAŁACIŃSKI T., WINIARSKI M., PRZESMYCKI A., ŚWIERCZ R., CHMIELEWSKI T. Applying titanium coatings on ceramics surfaces by rotating brushes. In: *METAL 2018: 27th International Conference on Metallurgy and Materials.* Brno: TANGER, 2018, pp.1235-1240.

[8] SCHAFER, F., *Entgraten*. Mainz: Krausskopf verlag, 1975.

[9] XEBEC. *XEBEC Brush Product Catalog* [online]. [viewed 10.04.2020] Available from: https://www.xebec-tech.com/cn/support/dpdi6o0000000cmi-att/cf_cup_en_02.pdf.

[10] ZALESKI, K., MATUSZAK, J. *Podstawy obróbki ubytkowej*. Lublin: Politechnika Lubelska, 2016.