EFFECT OF CUTTING EDGE PREPARATION TECHNOLOGIES ON SURFACE ROUGHNESS, PROCESSING TIME AND K- FACTOR

ANETA SLANINKOVA[1], JAN JANSA[1], RADIM JANECZKO[1], IVAN MRKVICA[1], MAREK PAGAC[1], TIBOR JURGA[1]

[1]Department of Machining, Assembly and Engineering Metrology, Faculty of Mechanical Engineering, VSB – Technical Univesity of Ostrava

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Email: aneta.slaninkova@vsb.cz

The geometry of the cutting tool is a crucial factor in its life and performance during the cutting process. In particular, the micro-geometry of the tool, which defines the shape of the cutting edge, has a significant effect on plastic deformation, heat generation, and cutting tool life. This article compares three technologies for removing material from cutting tools: wet blasting, dry blasting, and brushing. The focus was on measuring the processing time for each technology to determine its productivity and processing the cutting edge to a specific value. The surface roughness parameters R_a and R_z on the cutting edge were also measured. The K-factor parameter was monitored for the repeatability of the cutting edge process. The results of the experiment indicate that selecting the appropriate cutting edge technology can positively impact both the productivity and roughness of the tool edge.

KEYWORDS

Cutting edge preparation, wet blasting, dry blasting, brushing, edge micro-geometry, K-factor, insert

1 INTRODUCTION

The grinding process of sintered carbide results in plastic deformation and micro-defects on the surface and especially at the cutting edge of the tools, such as burrs, cracks, or high surface roughness [Rodriguez 2009]. The cutting edge has after grinding an almost sharp shape (approximately 5 µm), which is not suitable for most machining applications due to high mechanical load leading to tool wear and reduced tool life [Denkena 2013]. These factors shorten the tool life and reduce the performance of the cutting process and must be removed to achieve optimal tool performance [Denkena 2014]. It also directly impacts the workpiece's surface finish, tool chatter, machining tolerances and tool wear resistance [Zlámal 2018], [Antic 2013]. [Zhuang 2021] stated it exists eight types of edge design, which he defined in his study. In commercially produced cutting tools, rounding (honed), chamfer-edge or a combination of rounding and chamfering is most commonly used as an edge processing. The choice of the appropriate cutting edge preparation depends mainly on the application of the specific cutting tool. [Denkena 2011] and [Lukic 2020] in his study, confirmed that the rounded shape of the microgeometry significantly affects the thermomechanical loading of the cutting tool. He also points out the need to investigate the roughness of the cutting tool, which is of great importance for chip flow [Shaw, 2005], [Antic, 2013], cutting forces [Dai 2019] and temperature in the cutting zone [Segebade, 2018].

To address these issues, cutting edge preparation operations are performed in the production process of sintered carbide cutting tools, aimed at eliminating micro-defects, increasing mechanical resistance, improving surface integrity, and enhancing coating adhesion. Common cutting edge preparation technologies using mechanical material removal are wet blasting, dry blasting, brushing, drug finishing, and grinding. In addition to methods based on mechanical material removal, unconventional technologies can be encountered, such as laser machining [Zimmermann 2020], and magnetic-abrasive machining [Denkena 2014]. Plasma discharges in the electrolyte can also be used [Vopat 2019].

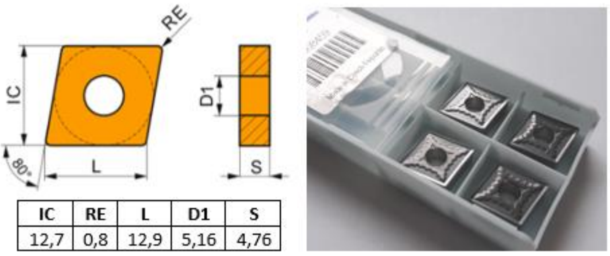
[Wang 2019] examined the influence of brushing, drug finish, and wet blasting technologies on tool surface properties, tool performance, cutting forces, and machined surface finish during orthogonal machining of AISI 4140 alloy steel. The samples were rounded to 20±5 µm. The results proved that the cutting edge rounded by wet blasting using alumina media with a grain size of 58 µm and a pressure magnitude of 0.5 MPa achieved the highest roughness of $R_a = 0.1311$ µm in the cutting edge region. It was also confirmed that wet blasting technology induces up to 62.7 % more pressure stress in the surface layers compared to the untreated surface. [Wang 2020] studied the relationship between the geometry and integrity of the prepared edges and their combined impact on tool performance. Machining showed that cutting edge preparation has a positive effect on flank wear growth rate and tool life. The performance of the tool depends on the microgeometry and also on the integrity of the prepared edge. [Jacob 2015] stated, that cutting tool modification using wet blasting significantly increases the adhesion of the coating. [Denkena 2010] found that the rounded edge is independent of applied infeed and cutting speed respectively. Therefore, they investigated 5-axis brushing which can achieve different variations of the K-factor through flexible adjustment of process parameters.

It exists a significant number of studies deal with cutting edge preparation and its effect on cutting tool performance and tool life. Conversely, there is limited research addressing the productivity of individual technologies and the suitability of abrasive media. In particular, the reproducibility of the cutting edge preparation process also needs to be addressed. Therefore, this paper focuses on the comparison of wet blasting, dry blasting, and brushing technologies in relation to the achieved surface roughness on cutting edge, productivity, and repeatability of the process respectively the achieved K-factor value.

2 DESIGN OF EXPERIMENT

2.1 Experimental procedure

Ground insert samples of type CNMG 120408E (Fig. 1) with SM chip former and negative geometry were used for the experiment. Inserts were manufactured out of fine-grained sintered carbide on the basis of WC-Co. After cutting edge preparation inserts are coated by PVD technology and are applicable for turning ISO series P25 - P40/M20 - M35 for fine to heavy steel machining and K20 - K40 for fine to heavy casted iron machining.



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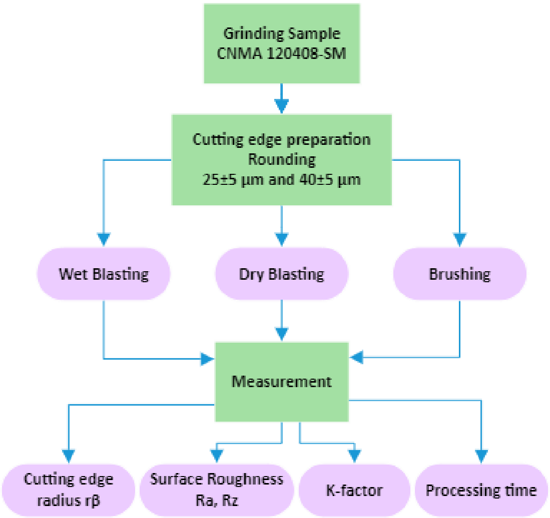
12,7	0,8	12,9	5,16	4,76

Figure 1. Inserts CNMA 120408E-SM

The inserts rounding was done using three cutting edge technologies: dry blasting, wet blasting, and brushing. Each technology produced a rounding of 25±5 µm and 40±5 µm. The roundness measurement r_β, the roughness parameters R_a, R_z, and K-factor value were measured on an Alicona IF-EdgeMaster 3D non-contact measuring device using the built-in Edge Master module. A magnification of 10x, was chosen for the 3D scan. In total, 32 inserts were measured and evaluated (for one technology, 5 inserts for rounding 25±5 µm and 5 inserts for rounding 40±5 µm). Measurements were performed parallel to the cutting edge, where the cutting edge characteristics were measured 4 times on each insert, and then the average value was calculated. The productivity, i.e. processing time, was measured for the 100 inserts fabrication. Subsequently, the magnitude of the K-factor determining the symmetry of the blade was evaluated, which affects mainly the force and thermal load on the blade. This parameter was used to represent the repeatability of production and whether the same K-factor value was achieved for a particular production batch respectively. Different k-factor values may lead to various machining process conditions. A schematic of the experiment is in Fig. 2.

Figure 2. Design of experiment



2.2 *Cutting edge preparation technologies*

Dry blasting

Material removal on the cutting edge is realized by the action of abrasive particles thrown toward the insert edge under high pressure in a carrier medium, which is compressed air. The impact of the abrasive particles results in the desired rounding of the cutting edge depending on the set process parameters of the technology. A brown aluminum oxide medium with a grain size of 150-220 mesh (approximately 74 µm) was used to round the blade, and the process pressure was set to 0.4 MPa. Cutting edge preparation was performed on an automatic blasting station. Only one insert can be placed in the working area of the machine, which is subsequently replaced by a robotic arm.

Wet blasting

Wet blasting technology works on a similar principle to dry blasting. The main difference is that the carrier medium is water, which brings several advantages. [Dankena et al. 2014] reported that water has a damping effect when the abrasive media hits the surface of the cutting tool, which causes better surface quality. At the same time, water suppresses dust formation, reducing the likelihood of health problems associated with breathing airborne particles. Inserts rounding was carried out on a machine Graf Station 8. The rounding process was performed by blasting 180-220 mesh (approx. 74 µm) pink aluminum oxide Al_2O_3 particles using 8 nozzles. The process pressure was set to 0.4 MPa and inserts were placed in a pallet jig capable of holding 56 inserts.

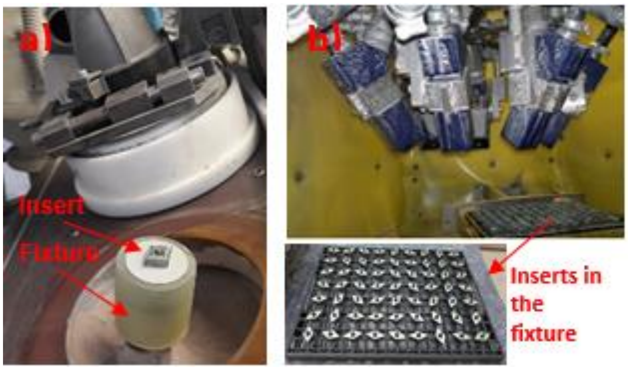


Figure 3. Dry blasting (a) and wet blasting (b) process

Brushing

It is a cutting edge preparation technology with an undefined blade. Circular brushes are most commonly used for cutting edge preparation consisting of extruded polymer fibers with dispersed abrasive particles. The rotary movement of the brush and the movement of the fibers with abrasive particles results in the desired cutting edge rounding. The size and condition of the cutting edge depend mainly on the type of brush tool used.

The brushing process was carried out on a SINJET IBX 12 machine from OSBORN manufacturer. The base of the machine is equipped with a turntable, which contains 12 spindles in groups of 4 spindles into which inserts are placed. In addition, fixtures are placed in the spindles having the shape of the insert to be treated and thus ensure the fixation of the insert during the brushing process (Fig. 4). Two types of abrasive brushes discs with nylon fibers were chosen - brush tool 80 SiC and brush tool 240 SiC REC. Brush tool 80 SiC has circular cross-section fibers with abrasive silicon carbide particles with a grit size of F80 according to FEPA standard.

Figure 4. Inserts placed in a jig (on the left) and microscopic photo of brush tool 80SiC (on the right)

A microscopic view of the brush tool 80SiC with visible abrasive particles is shown in Fig. 4. The second type of brush tool, 240 SiC REC, contains silicon carbide abrasives with a grain size of F240 with fibers of rectangular cross-section. A higher number according to the FEPA standard characterizes finer grains.

3 RESULTS AND DISCUSION

3.2 *Processing time*

The productivity of all three technologies investigated was expressed in terms of processing time. It is the time when 100 pieces of inserts were rounded. The measurement results are shown on the graph in Fig. 5. The wet blasting technology achieved the highest productivity, and the lowest time to achieve roundness of 25±5 µm and 40±5 µm, respectively. Almost comparable results were achieved with the brushing technology. When comparing the two types of brushes, it was found that higher productivity was achieved by brush tool 240 SiC REC. It can be assumed that the finer grit and rectangular cross-section of the filament guarantee higher productivity compared to a brush with a circular filament cross-section and coarser grit. The lowest productivity was gained by dry blasting. That is mainly because only one insert can be sand-blasted at a time on the automatic blasting station, which reduces the productivity of this technology.

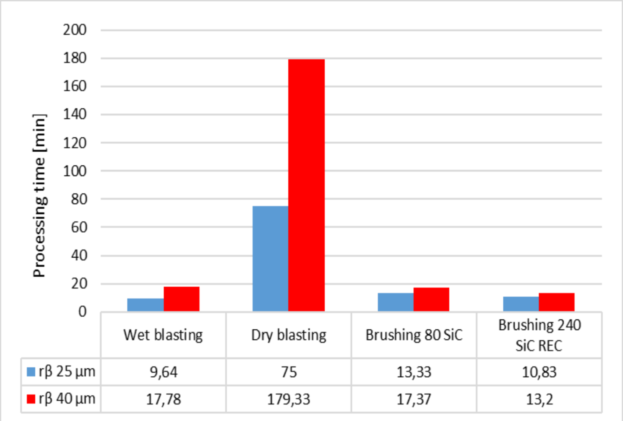


Figure 5. Achieved values of processing time depending on the achieved roundness size r_β

3.1 *Surface roughness*

For evaluation of the experimental activity, the two most commonly used parameters were selected, namely: the arithmetic mean deviation R_a /µm/ and maximum height R_z /µm/, or the sum of the height of the highest profile protrusion and the depth of the lowest profile depression in the range of the basic length l_r /mm/. Measurement was conducted according to standard CSN EN ISO 4287. The measured data results are shown in graphs in Fig. 6 and Fig. 7.

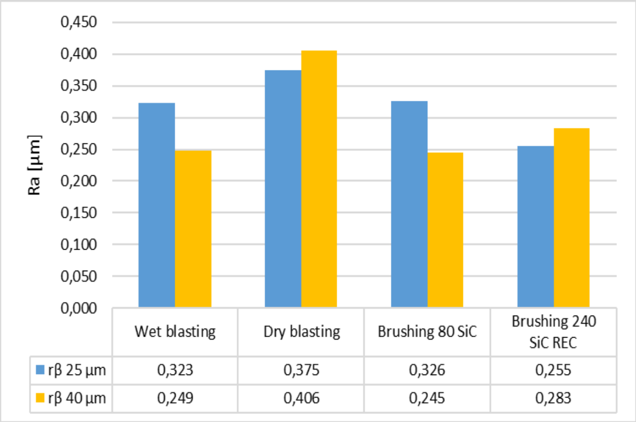


Figure 6. Arithmetic Mean Deviation of the roughness profile R_a v závislosti na dosažené velikosti zaoblení r_β

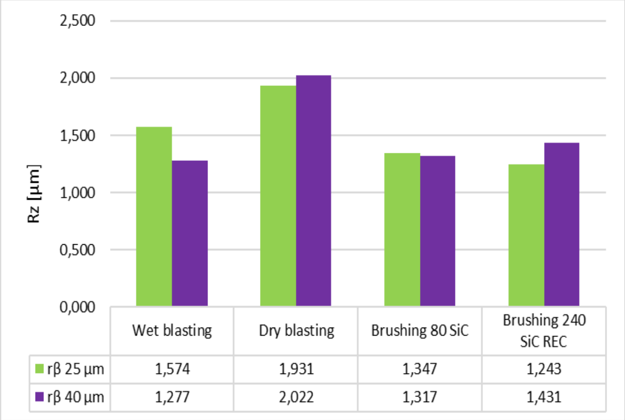


Figure 7. Maximum height of the roughness profile R_z depending on the achieved roundness size r_β

The highest values of R_a and R_z were achieved by dry blasting. A trend can be observed that with increasing rounding value, there is a significant increase in the roughness parameters R_a, R_z at the cutting edge. On the other hand, wet blasting technology indicates that water as a carrier medium has a smoothing effect and there is a decrease in roughness with an increasing rounding value. When rounding to 25±5 µm, significantly higher values of the R_a parameter were achieved with brush tool 80 SiC than with brush tool 240 SiC REC. As the cutting edge value increases, there is a significant decrease in the R_a parameter for the brushing 80 SiC technology, whereas for the brush tool 240 SiC REC, both R_a and R_z increase. These results suggest that coarser grit size and circular cross section of the brush tool lead to a roughness reduction at the cutting edge.

Fig. 8 showns SEM images taken on a rake face. In samples of rounded brushing technologies, brush tool fiber marks can be observed on the rake face. In dry blasting technology, the pitting caused by the impact of abrasive alumina particles is visible, while wet blasting technology has a smoother texture due to the effect of the water carrier.

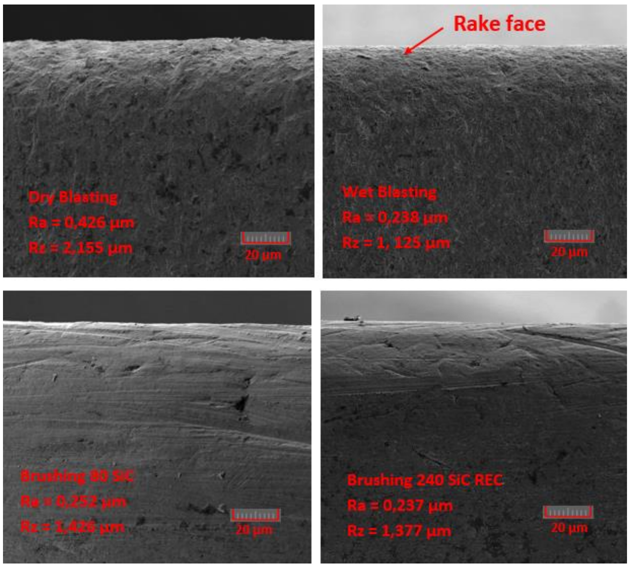


Figure 8. SEM images of the rake face

3.3 K-factor

[Dankeena 2014] introduced the K-Factor method, which more accurately describes the micro-geometry of the cutting tool. The cutting edge parameters are presented in Fig. 9. The form factor is defined as the ratio of the length of the edge radius along the rake face (Sγ) to the length along the flank face (Sα). [Fulemová 2015] confirmed that the K-factor value has a significant effect on tool life and surface roughness and the best results are achieved with values K > 1. There are three types of K-factor, namely: As for asymmetry cutting edge (K < 1) is defined as waterfall hone and (K > 1) is defined as trumpet hone, and symmetry cutting edge defined as (K = 1). Profile flattening Δr and apex angle φ, which are measured by the shortest distance and the shift between the ideal sharp cutting edge tip and the actual shape of rounding, respectively, are used to characterize the tools' bluntness.

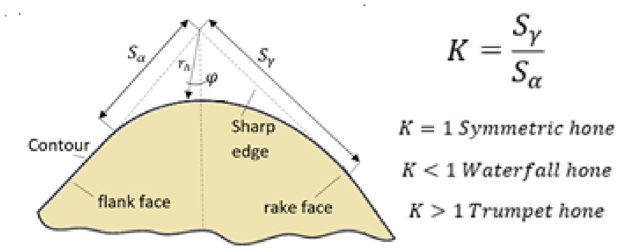


Figure 9. K-factor definition on cutting edge

The K-factor value in this study was used to compare the production repeatability of each technology. The graph in Fig. 10 presents the K-factor values of all measured samples (20 inserts). For wet blasting and dry blasting technology, K > 1 trumpet hone was achieved. On the contrary, the brushing 80 SiC REC technology showed half of the k-factor values – waterfall hone. The brushing 240 SiC REC technology shows all types of K-factor: K=1, K>1, and K<1. This may induce different cutting tool behavior during the machining process.

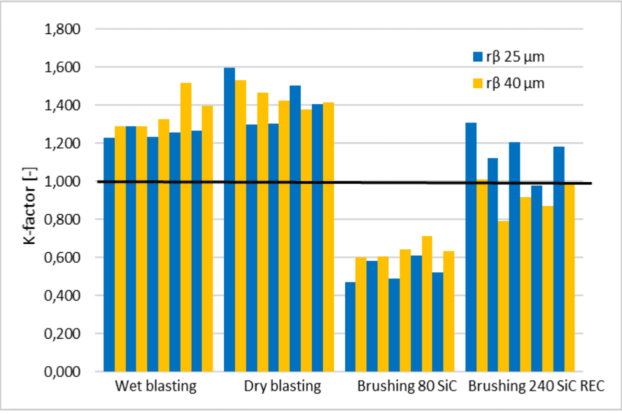
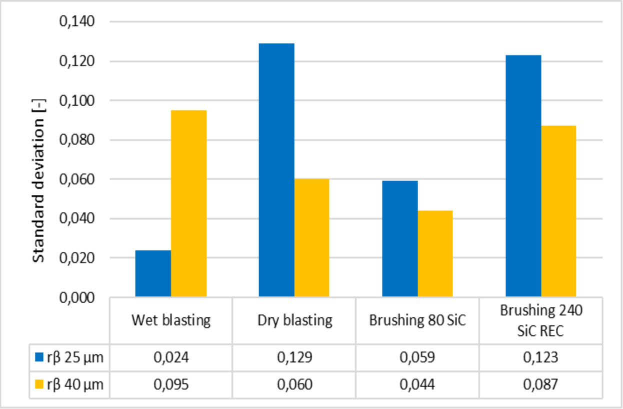


Figure 10. Achieved K-factor values of measured samples

The standard deviation of the K-factor was calculated to express the repeatability of production, From the graph in Fig. 11, it can be observed that at roundness values of 25±5 µm, the most stable values were achieved using wet blasting technology. On the contrary, as the rounding value increased, repeatability decreased significantly. The dry blasting technology guaranteed higher repeatability especially with increasing roundness value, as did the brushing technology.

Figure 11. Achieved K-factor standard deviation values



	Wet blasting	Dry blasting	Brushing 80 SiC	Brushing 240 SiC REC
■ rβ 25 µm	0,024	0,129	0,059	0,123
■ rβ 40 µm	0,095	0,060	0,044	0,087

4 CONCLUSIONS

The results of this study indicate that the edge roughness, productivity, and repeatability of the process in relation to the achieved roundness of 25±5 µm and 40±5 µm on the cutting edge is significantly influenced by the chosen technology.

According to the results obtained, wet blasting appears to be the most suitable technology for cutting edge preparation. The roughness value decreased significantly with increasing roundness value and an average value of roughness parameter R_a = 0,249 µm was achieved at r_β = 40±5 µm. The productivity of the technology was almost comparable to the brushing technology.

Dry blasting technology versus wet blasting and grinding technology was evaluated in this experiment as unsuitable for edge rounding due to high roughness at the cutting edge and low productivity. The K-factor value was defined as waterfall honed K>1. The repeatability of producing the same rounding value increased with increasing rounding value.

By using two types of abrasive tools with nylon fibres and SiC abrasive particles, it was found that different fiber cross-sections and grit values have different effects on the monitored parameters. The coarser grit size and circular cross section of the 80 SiC brush tool guarantee lower productivity than the 240 SiC REC brush tool. The parameters R_a and R_z decrease with increasing roundness value r_β, while the roughness at the cutting edge increases for brush tool 240 SiC REC. The K-factor value for brush tool 80 SiC was K < 1 for all measured samples. On the other hand, a large variance between the K-factor values was obtained for brush tool 240 SiC REC, where all types of K-factor were measured.

From the results obtained, it is evident that the influence of the abrasive media used for each technology and their impact on the roundness size, and roughness of the cutting edge needs to be further investigated. The lifetime of cutting edge preparation cutting tools and their effect on the cutting process also needs to be verified. Furthermore, the reproducibility of each technology needs to be investigated in more detail so that comparable values of the parameters defining the cutting edge are achieved in each production batch. In the future study it is also planned to focus not only on the influence of abrasive media but also on the process parameters of dry blasting, wet blasting and brushing technologies.

The obtained results of surface roughness, process time and k-factor can be the basis for further experimental studies in the field of cutting edge preparation.

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CONTACTS:

Aneta Slaninkova, MSc

VŠB-Technical Univesity of Ostrava, Faculty of Mechanical Engineering, Department of Machining, Assembly and Engineering Metrology,

17.listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic,

+420 597 324 451, aneta.slaninkova@vsb.cz, www.fs.vsb.cz