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CUTTING EDGE PREPARATION METHODS COMPARISON IN TERMS OF TOOL LIFE

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Abstract

The paper deals with three cutting edge preparation methods, namely brushing, drag finishing and abrasive jet machining. The cutting edge radius of 35 µm was prepared with each of these methods. The influence of used preparation methods on the tool life was investigated. Cutting tests were carried out during the turning of a difficult-to-cut nickel alloy Inconel 718. The chosen cutting parameters were considered for the semi-finishing turning operation. The longest tool life was achieved with drag finishing. The findings can be used to improve the efficiency of the turning process of nickel alloy Inconel 718.

Keywords: Cutting edge; Edge preparation; Tool life; Tool wear; Surface finishing

1. Introduction

The important aspect of the machinability of material, which was a topic of interest over the last 100 years is cutting edge geometry [1]. The tool life, coat adhesion and quality of machined surface are also influenced by it. Proper edge geometry stabilizes the cutting edge, which leads to the reduction of residual stresses in the cutting tool and improvement of the tool behaviour. The way to achieve such geometries on the cutting edge is preparation. It is usually carried out after the grinding of the tool and before coating [2], [3]. Denkena et al. showed that the tool life can be increase by 80% with an asymmetrical cutting edge rounding tilted to the rake face when machining C45E steel [4]. The research [5] found out that by enlarging the microgeometry of the cutting edge, the mechanical stress on the cutting tool is significantly reduced but it is also linked to an increase in the thermal load in the tool. The article demonstrates a 70% reduction of the wear on the flank face when milling 42CRMo4-QT steel with milling tools with rounded cutting edges [6]. Ventura et al. used a tools with cutting edges with multiple chamfers and found out that more chamfers on the cutting edge increased tool life and compressive residual stresses on the finished surface but increases the cutting forces slightly [7]. The scanning laser interferometry was used in the article [8] to analyse, characterize, and verify the micro-geometry of the complex cutting edges when machining of Ti-6Al4V material. The research discovered an interaction between kinematic roughness and hone size of the cutting edge. It revealed that with larger hones the roughness increases or decreases depending on the kinematic roughness.

There are various cutting edge preparation methods, the most used ones in industry are brushing, drag finishing and abrasive jet machining. There are also new and progressive methods such as abrasive flow machining, magneto abrasive machining, laser machining, electrical discharge machining [9] or plasma discharge machining [10].

The abrasive jet machining is a process, where the material is removed trough erosion by an abrasive particle jet. A mixture of abrasive media is sprayed on the tool surface trough a jet nozzle. There are two types of this process. Dry abrasive jet machining uses air as a medium and the water is chosen for the wet abrasive jet machining. It is an effective method for creating cutting edges with reasonably accurate edge geometry [11]. Wyen discovered that the lack of thermally induced distortions on the machined surface is one of the most notable benefits of wet abrasive jet machining [12]. According to Jacob, the abrasive jet machining of the tool substrate may enhance coating adhesion. It could be used after coating to improve the hardness of the cutting edge. After the preparation procedure, the cutting tool had lower tool wear at a higher cutting speed [13]. The research of Bouzakis et al. showed that the abrasive jet machining may be used to precisely generate complicated cutting edge designs, while also enhancing the toughness and reliability of the cutting edge. Additionally, the procedure can induce compressive stress to the tool subsurface, improving the PVD coated tool film strength and tool performance [14]. The benefits of abrasive jet machining on cutting inserts for turning still require additional research due to a corresponding lack of studies.

Brushing allows to produce defined cutting edges with symmetrical and asymmetrical shape. For this reason, rotating circular brushes with filaments typically made of extruded polymer fibres containing scattered abrasive particles, such as silicon carbide or polycrystalline diamond, are frequently used [15]. It was first introduced as a novel 5-axis approach for the machining of cutting edges by Denkena et al. In their research, the fundamental effect of the brushing process parameters was examined. The cutting edges of carbide cutting inserts were machined using SiC 500 brushing tools, It has been demonstrated that the brushing process can be used to create customized microgeometries [16]. Using the same setup, they reported more research on the brushing process parameters in the subsequent study. It was demonstrated that the infeed and cutting speed had a considerable impact on the size of the cutting edge rounding. They also found out that the angle between cutting edge and the brushing tool affects the shape of the cutting edge. In the article it was shown that the tool life of the cutting inserts prepared by brushing could be increased by 100% compared to a tools without preparation [17].

Drag finishing is a machining process, where the workpiece is placed into a container filled with free abrasive grains with geometrically undefined cutting edges. This process is employed when parts need to have good surface quality, because it has the benefit of production of the desired results in a short time. It is quicker and more effective when compared to other processes, thanks to increase of the media pressure and relative speed between the media and surface of the workpiece. By changing specific process parameters, such as the feed rate, process time or the kind of grains, it can also be employed for the preparation of the cutting tools [18], [19]. Several researchers have studied the impact of media and their speed in the context of drag finishing. According to Barletta et al., the effectiveness of drag finishing is proportional to the both the impact forces and the kinematic energy of the medium [20]. Research of Kacaras et al. shows that the higher rotating speed result in greater impact forces and a quicker improvement of the surface [21].

The effect of cutting edge preparation on cutting forces was examined in publication [22]. Influence of cutting edge radius sizes on the tool life was determined in publication [23] The purpose of the article in [24] was to determine the accuracy of solid cemented carbide mills manufactured on grinding machine and determine the influence of drag finishing on macro geometry of solid cemented carbide mills. The purpose of this paper is to examine the difference between three cutting edge preparation methods, namely brushing, drag finishing and abrasive jet machining, and their influence on cutting inserts in terms of tool life in turning difficult-to-cut nickel alloy Inconel 718 equivalent to EN NiCr19FeNbMo.

2. Materials and methods

The manufacturer former Pramet produced double-sided negative cutting inserts for the research. They were PVD coated and made of WC-Co cemented carbide. The designation of the cutting inserts is CNMG 120408-SM. Steel toolholder with designation PCLNL 2020k16 was used. These cutting inserts are suitable for machining steel, superalloys, hard materials, and for finishing or semi-roughing operations. The specifications of the cutting inserts are shown in Table 1. The cutting inserts were prepared by brushing (B), drag-finishing (DF) and abrasive jet machining (AJ). The cutting edge radius created with each of the preparation method was r_n = 35 µm.

Parameter	Value	Parameter	Value
Length [mm]	12.90	Recommended f [mm]	0.15 – 0.45
Thickness [mm]	4.76	Recommended a_p [mm]	0.80 – 4.00
Nose radius [mm]	0.80	Cutting edge angel [°]	80.00

Table 1. Cutting tool parameters

The measurement of the cutting edge radius was carried out by Alicona InfiniteFocusSL 3D measurement system. It is shown in Fig. 1 for the cutting edge prepared with brushing. The machine tool used in the experiment was a CTX Alpha 500 multi-axis turning centre. The machine tool parameters are in Table 2. During the cutting tests, a longitudinal turning strategy was used. Throughout the whole machining process, the cutting conditions remained unchanged. The process parameters chosen were the cutting speed of v_c = 40 mm·min^{-1}, the feed of f = 0.15 mm, and the depth of cut of a_p = 1 mm. They were used to control the development of wear at the cutting edges.

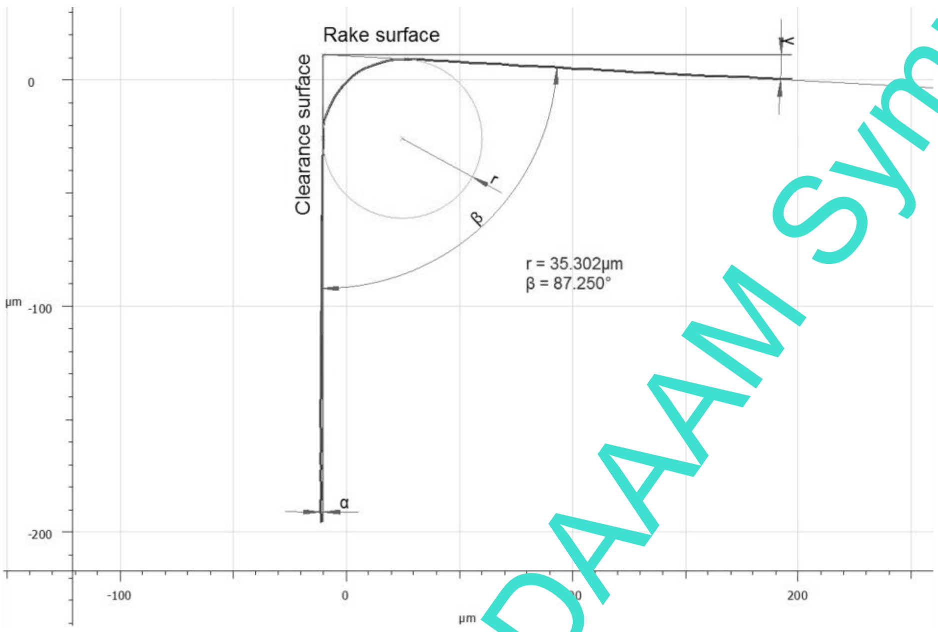

Fig. 1. Example of measurement of the r_n prepared by brushing

Travel distance		**Tool revolver head**	
X [mm]	190	Number of tool positions [-]	12
Y [mm]	±40	Drive power [kW]	5.4
Z [mm]	525	Max. rotation frequency [min-1]	5000
Main spindle		Control system	Heidenhain CNC Pilot 4290
Drive power [kW]	20		
Max. rotation frequency [min-1]	6000		

Table 2. Parameters of CTX Alpha 500 multi-axis turning centre

The material for the workpiece was Inconel 718 (equivalent to EN NiCr19FeNbMo). It is a high strength nickel-chromium alloy that has been annealed. Cold working was used to manufacture the workpiece. The chemical composition of the workpiece material is in Table 3.

C	**Si**	**Mn**	**N**	**Cr**	**Mo**	**Ni**	**Cu**	**Co**	**Ti**	**Al**	**Nb**	**Fe**
0.023	0.070	0.[illegible]1	0.006	17.780	2.990	53.6	0.06	0.35	0.9	0.4	5.1	18.2

Table 3. Chemical composition of the Inconel 718 (wt. %)

The length of the wear area VB_N was measured by a Dino-Lite Edge microscope with a resolution of 1280 × 960 pixels. The cutting inserts were cleaned prior to experiment since the cutting edges had impurities. The workpiece material was clamped into the three-jaw chuck of the main spindle and machined using three cutting inserts prepared with the same method. The diameter of the workpiece was 101.6 mm. The machined surface was 60 mm in length. During the process of manufacturing the workpiece, the top layer become strain hardened. This layer is thinner than 0.3 mm. To avoid influencing the experiment's outcome, another cutting insert was used to machine this layer.

The first cutting insert had a cutting length range of 0 to 20 mm. The cutting length ranged from 20 to 40 mm for the second cutting insert and from the 40 to 60 mm for the final one. The cutting inserts were cleaned after the first minute of machining. Then, they were inserted into the customized holder that was created using 3D printer. The microscope was focused on the cutting edge. It was captured in the photo so that it could not be moved by outside sources that would have affected the measurement of tool wear. The flank wear was then measured in the image. The experiment continued after it was recorded, with cutting inserts being placed back to their positions in the turning centre. Tool wear was then measured every 2 minutes of machining until the tool wear started to increase significantly or edge chipping was observed on the cutting insert.

3. Results and discussions

The time dependence of the average tool wear with respect to the preparation method is shown in Fig. 3. For the experiment, three cutting inserts were used for each method with the prepared cutting edge radius of r_n = 35 μm with respect to statistical significance. The designation of the preparation methods in the Fig. 3 is as follows: DF is for drag-finishing, AJ is for abrasive jet machining and the B is for brushing.

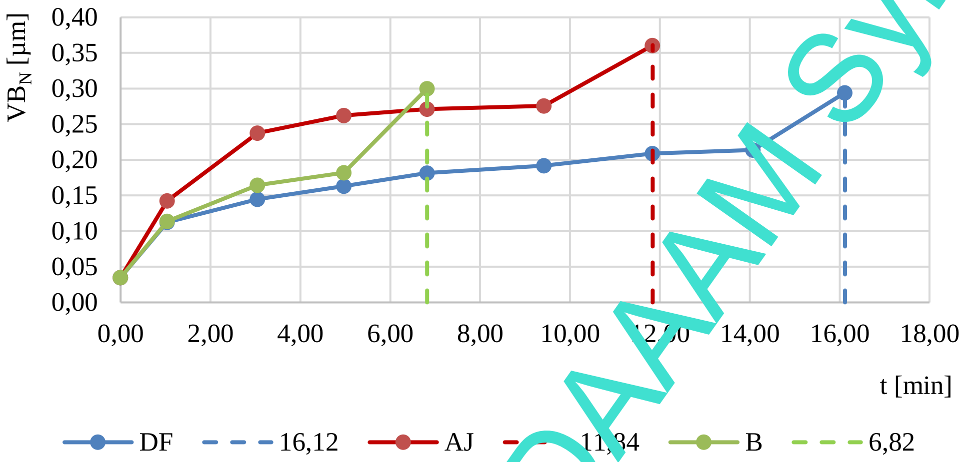

Fig. 2. Average wear development for cutting edges prepared with different methods

The longest tool life was achieved with the cutting inserts prepared with drag-finishing with a value of 16.12 minutes. The tool life increased by 36.15% compared to abrasive jet machining and by 136.36% compared to brushing. This increase in the tool life can be explained by the fact that the shape of the cutting edge is more uniform and that the adhesion of the coat to the substrate is better after the drag-finishing when compared to the other two used preparation methods. Tool wear can be difficult to predict when dealing with difficult-to-cut materials such as nickel alloys. As a result, it occasionally happens that the cutting tool breaks earlier than anticipated. This is also a reason why the shorter tool life occurred in some cases.

4. Conclusion

The topic of the paper deals with cutting edge preparation of cutting inserts made of cemented carbide. When cutting difficult-to-cut nickel alloy Inconel 718, the effect of 3 cutting edge preparation methods on the tool life was examined. The cutting edge radius prepared with each method was 35 μm. The cutting parameters were chosen in consideration of the semi-finishing turning operation.

The tool life tests showed that the longest tool life was reached with drag-finishing. The average tool life was 16.12 minutes. It was increased by 36% when compared to abrasive jet machining and by 136% compared to brushing.

Future research will examine the effect of more cutting edge radii within each method on the tool life and cutting forces during turning operations as well as their effect on the surface roughness parameters. The preparation methods will be compared with each other in these terms as well.

5. Acknowledgements

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