ABSTRACT
The need for new cutting tool technologies is driven by the frequently increasing performance of machine tools and the rising market competition. An improved combination between macro and micro geometry of the cutting edge, followed by the appropriate coating, is essential for the progress of cutting tool performance and tool life. To explore such combinations, the ability to produce tailored cutting edge micro geometries with variable radii is necessary. Furthermore, it is important to achieve a homogeneous rounding along the major and minor cutting edge and corner, in order not to impair the coatings quality at these areas and, therefore, to ensure a stable performance of the cutting tool. This paper introduces a 5-Axes brushing technology developed for the preparation of designed micro geometries of cutting tool.

KEYWORDS: Microgeometry, Cutting Edge Preparation, Brushing, Residual Stress

1 INTRODUCTION
Current research shows that the tool microgeometry has a very important influence on the cutting process /1/. Therefore, there is an increasing interest in the behaviour of prepared cutting tools and their tool life. The productivity of a cutting process can be enhanced by optimising the microgeometry of the cutting edge /2/. The microgeometry can even affect the surface residual stress status of the workpiece /3/. There are many ways for preparing the cutting edges. By using microblasting, brushing, microfinish or even laser techniques it is possible to achieve roundness on the sharp cutting edge. Every technique has its application field depending on its productivity, accuracy and the intended shape of the microgeometry. The shape of the microgeometry can be consistently characterized using the parameters $\Delta r$, $S_\alpha$, $S_\gamma$ and the ratio $K$ instead of using only the radius of the roundness $r_\beta$ (figure 1).

Figure 1: Consistent characterization of the cutting edge microgeometry of an insert.
By using this kind of characterization of the microgeometry it is possible to distinguish three tendencies. \( K = 1 \) defines a symmetrical micro geometry; \( K > 1 \) indicates a slope toward the rake face of the insert and \( K < 1 \) describes a slope towards flank face /1/ (Figure 2).

![Figure 2: Different cutting edge forms; consistent characterized.](image)

The microgeometry can be measured using tactile, optical, via SEM or confocal laser based measurement devices. In all these measurement methods the profile of the microgeometry is obtained perpendicular to the cutting edge (cross section) and given out graphically or exported as an ASCII-Data, which can be separately evaluated.

2 CUTTING EDGE PREPARATION THROUGH BRUSHING

Brushing tools are widely spread in the industrial field for wide range of applications such as surface finishing, polishing or burr removal. They are also used for cutting edge preparation in form of wheel or disk brushes (Figure 3). Brushing tools filaments are manufactured from extruded polymer fibers. The fibers contain dispersed abrasive material such as SiC or PCD Particles, which usually make 30-40% of the total volume. Little information is found in the literature about the material removal rate and the wear mechanisms of the filaments. A variability of the cutting edge has been observed along the cutting edge and the insert corner. This is due to the complexity of a brushing process /4/. Some research aimed at the relationship between the brush interface pressure and the material removal rate /5/, /6/. Though, the wear mechanisms depend on the kind of the abrasive and brushed material, in addition to the process parameters such as cutting speed, brushing time and feed rate.

The conventional and the 5-axes brushing of WC inserts using wheel brushes will be presented in the following chapter. The advantages and properties of the new method will be discussed.
2.1 Conventional brushing techniques using radial brushes

Using wheel brushes it is possible to prepare the cutting edge of an insert. The filaments will climb on the sharp cutting edge and remove the material with the wear surface of there tips. In this case it is practically only possible to prepare the inserts by brushing them from flank to the rake face. A similar situation is found with disk brushes. Nevertheless, depending on the desired shape of the microgeometry it is important to choose the appropriate process parameters and brushing technique. The process parameters by brushing are cutting speed \( v_c \) [m/s], infeed \( a_e \) [mm], cutting time [s] and the feed rate \( v_f \) [mm/min].

Varying these parameter leads to different shapes of roundness of the cutting edge. Different cutting edge microgeometries can be generated according to the set of parameter chosen. Increasing the brushing time using wheel brushes will increase \( S_\gamma \) and \( S_\alpha \) almost equally, so that the ratio \( K \) remains stable till a certain point of time. The ratio \( K \) decreases with the rapid increasing \( S_\alpha \), which can be achieved by increasing the infeed or the cutting speed. Critical points of time should not be exceeded. Then the rising temperature of the filaments and the inserts will affect the performance of the brush. That depends on the polymer sort and can cause a performance collapse of the brush. (Figure 4)

It is possible by adjusting the process parameters to influence the form of the roundness of the cutting edge. Nevertheless, this option stays limited by the brush kinematics and the fact that a critical brushing time should not be exceeded. Therefore it is important to change the contact condition between the brush and the insert, in order to change the material removal angle. This results in a change of the ratio \( K \).
2.2 5-Axes Brushing

The necessity of different forms of the microgeometry of a cutting edge led to the development of this 5-axes brushing method. Current research works established a direct influence of the form of the microgeometry on the tool life and efficiency /7/.

In this application a controlled change of the material removal direction can be achieved by adjusting the brushing path and direction when needed. The brush can move along the axes X, Y and Z. The insert is mounted in a special insert holder on the axes A and C and can draw the shown path by rotating them simultaneously. The brushing tool will also follow the same path of the insert and keep brushing the cutting edge with stable contact conditions and brushing parameters (Figure 5). The ratio $\kappa$ can be manipulated by changing the angle $\alpha \beta$. This angle, added to the usual brushing parameters, gives a better control of the achieved microgeometry. The movement path of the brush should be adjusted, if the angle $\alpha \beta$ is changed.

This method enables a homogenous rounding of the cutting edge along the major, minor cutting edge and within the cutting tool corner. The reason for this is the absence of overlapped brushing areas (Figure 6). Furthermore, it is possible to change the brushing direction, process parameters and even to combine two kinds of brushes at the same preparing process if needed. Therewith it is possible to prepare more different shapes of the microgeometry.

The resulting microgeometry is shown in Figure 6. This insert has been prepared with the new 5-axes brushing method using a SiC#500 brush. Notice the roundness at the insert corner and the transition points toward the major and minor cutting edge. It is also possible to achieve symmetrical and nonsymmetrical microgeometries.
3 RESIDUAL STRESS STATUS AND SURFACE TOPOGRAPHY

By means of the new cutting edge preparation technology it is possible to produce tailored microgeometries. That means to prepare the appropriate form of the microgeometry to suit the cutting process and its demands.

Furthermore, it is possible to influence the properties of the prepared cutting edge such as the state of the residual stresses and surface topography (Figure 7). An inappropriate distribution of the residual stresses in the substrate can lead to coating damages such as cohesive failure /8/.

Figure 5: S-axes brushing.

Figure 6: Prepared cutting edge of a WC-Insert.
Therefore, the influence of the brushing tools on the substrate has been investigated. The residual stress distribution has been measured applying the X-ray \( \sin^2 \psi \) method. This method presumes that there is no change of the residual stress status within the penetration depth of the X-rays /9/.

For these experiments two inserts have been prepared using two kinds of SiC-Brushes: SiC#240 and SiC#500. A third one has been prepared by a combination of both of the brushes. The measurements have been repeated three times each. All of the inserts were brushed with the same parameters (\( v_c = 30 \) m/s, \( a_e = 1 \) mm, \( t = 15 \) s). The residual stress status has been measured at the surface of the non coated substrate at three different points on the brushed flank surface. Comparing the results of the residual stress status before and after the cutting edge preparation it is clearly to notice the increasing compressive stress level. The SiC#500 brush is also able to build higher compressive stress up to 15\% than the SiC#240 brush. This effect can be explained by the higher density of filaments in the SiC#500-Brush.

By observing the resulting surface roughness at the cutting edge, higher values of \( R_a \) and \( R_z \) can be recognised. This could reveal the effect of a higher filament density of the brushes. The combination of the two brushes does not lead to any more reduction of the roughness or to a higher compressive stress level.

![Figure 7: Surface morphology and residual stress status](image)

**4 SUMMARY AND OUTLOOK**

Based on the fact that the microgeometry of the cutting edge can enhance the performance of the cutting tools and expand the tool life, it is important to study the effect of different forms of the microgeometry. Therefore, a new 5-axis brushing technique for inserts has been developed. The aim of this method is to achieve a controlled cutting edge preparation. By means of this method it is possible to create a homogeneous roundness along the cutting edge and even at the tool corner. Furthermore, the residual stress and surface roughness at the cutting edge can be affected. It is also possible to produce tailored microgeometries. The roundness along the
cutting edge can be prepared to suite the kind of turned material and the resulting process loads.

Due to the high repeatability of the machining process and the consistent defined micro geometry, it is possible to isolate and observe the influence of the brush wear on the resulting microgeometry and on the scatter of its dimensions. Critical brushing parameters for each kind of brushes can be found out, in order to achieve a higher reliability of the cutting edge preparation and optimize the brushing process.

5 REFERENCES
