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Cutting of steel X13NiMnCuAl4-2-1-1 with micro milling tools using a defined cutting edge preparation

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Abstract
An approach to improve the wear behaviour of micro milling tools is a defined cutting edge preparation applying immersed tumbling. In experimental investigations a 3-axes machine tool is used to analyze the influence of the wear behaviour of prepared micro milling tools with diameters D = 0.2 mm made of cemented carbide. During machining of steel X13NiMnCuAl4-2-1-1 the process behaviour is analyzed, the cutting forces F_c in the milling process are examined and the surface roughness of the workpiece is measured.

Keywords: micro milling, immersed tumbling

1. Introduction

Micro milling is characterized by a wide range of machinable materials, a high geometric flexibility, and short operation times t_n. One reason for premature tool failure in micro milling is irregular wear behaviour of the cutting edges due to high dynamic loads. Frequently after grinding of micro milling tools the cutting edges have small grain outbreaks which increase during the milling process and which advance the tool wear of the cutting edges [1]. With immersed tumbling Uhlmann et al. [2] were able to show that the technology can be used for the cutting edge preparation of micro milling tools with diameters of D ≥ 0.5 mm. Due to generation of defined edge radii r_β the cutting edge could be stabilized and the chipping of the cutting edge could be decreased. The results of the cutting edge preparation were a reduction of the flank wear land VB_{max} by 14 % and a decrease of the active force F_a up to 19 % based on the reduction of the surface roughness and the friction between the cutting tool, the chips, and workpiece [3].

Within this paper immersed tumbling is used for cutting edge preparation of micro milling tools with a diameter of D = 0.2 mm. Subsequent the process behaviour of these tools will be analysed and conclusions about the correlation between process behaviour and the defined cutting edge preparation will be made.

2. Cutting edge preparation of micro milling tools

For the cutting edge preparation a machine tool Otec DF-3 Tools made by the company OTEC PRÄZISIONSFINISH GMBH, Straubenhardt, Germany was used. The micro milling tools with a diameter of D = 0.2 mm were manufactured by the company GESAU-WERKZEUGE FABRIKATIONS- UND SERVICE-GMBH, Glauchau, Germany. In the machine tool the workpieces will clamped into workpiece holders. Subsequently, the workpieces are dragged through a process container with lapping media. Due to the impact and sliding of the media grains on the cutting tools material will be removed. Within the experiments the lapping media HSC 1/300 was used. This media consists of 30 % silicon carbide (SiC) with a grain diameter of d_G = 200 µm and 70 % walnut shell granulate with a grain diameter 0.8 mm ≤ d_G ≤ 1.3 mm. For the preparation process the main drive rotates with a rotational speed of n_R = 40 rpm and the workpiece holders with a rotational speed of n_H = 40 rpm, too. Furthermore the depth of immersion was T_E = 100 mm. The processing time was t_B = 0.5 min for tool group B and t_B = 1 min for tool group C. Figure 1 shows SEM images of the three tool groups.

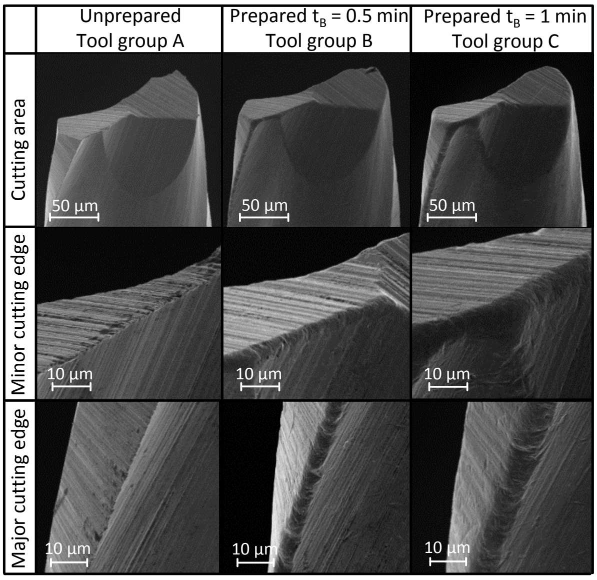

Figure 1. SEM images of the prepared tools

After the preparation, the cutting edges were measured with an optical measurement device InfiniteFocus of the company ALICONA IMAGING GMBH, Graz, Austria. Each group consists of four cutting tools. At a magnification of 50x five measurements for each measuring point were done. Figure 2 presents the results of the cuttings edge radius r_β of the minor and major cutting edge as well as the chipping of both edges R_s.

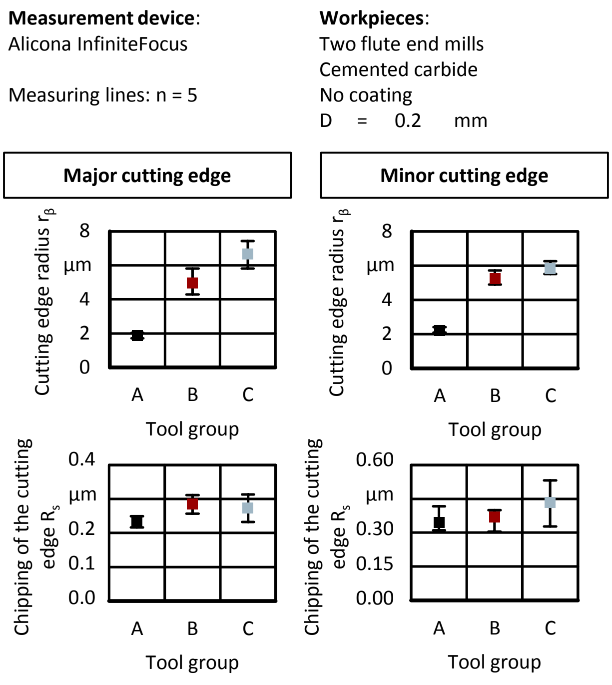

Figure 2. Cutting edge radius r_β and chipping of the cutting edge R_s

For unprepared micro milling tools a cutting edge radius of $r_\beta = 1.9$ µm was measured on the minor cutting edge and $r_\beta = 2.2$ µm on the major cutting edge. Through the preparation the cutting edge radius increase to $r_\beta = 4.9$ µm and $r_\beta = 5.3$ µm after $t_B = 0.5$ min and $r_\beta = 6.7$ µm and $r_\beta = 5.8$ µm after $t_B = 1$ min. The cutting edge preparation with the HSC 1/300 lapping media leads to an increase of the chipping of the edge R_s. The increase is justified by small scratches on the cutting edges by the impact and sliding of the media grains. With the rise of the processing time t_B the chipping of the edges increases continuously.

3. Machining of X13NiMnCuAl4-2-1-1

For the experimental investigations a 3-axes micro milling machine tool Wissner Gamma 303 HP was used. With a spindle Precise SC3062 a maximum rotational speed of n = 60 000 rpm can be reached and the position accuracy of the machine as well as the true running accuracy of the used spindle is 2 µm. The machine tool was extended with a piezoelectric dynamometer MiniDyn 9256B2 of the company Kistler Instrumente AG, Winterthur, Switzerland. With the dynamometer the forces in x-, y- and z-direction can be measured and the cutting force F_c can be determined. Subsequent of the experimental investigations the surface roughness, presented by the arithmetical mean deviation Ra and the mean roughness depth Rz, was measured with a measurement device InfiniteFocus.

The first chart in Figure 3 shows the average active forces F_a of the three tool groups. During the experiments the measured forces were between $F_a = 0.3$ N and $F_a = 1.1$ N. For unprepared cutting tools it is shown that the forces have larger fluctuations in comparison with prepared tools of tool group B and C. The tool group B requires the highest cutting forces F_c and group C the lowest during the experiments. The reason for that is the influence of the cutting edge radius r_β on the chip formation. A higher radius r_β changes the relationship between the displaced and machined material. With an increasing radius r_β the active force F_a decrease and the passive force F_p rise up.

Furthermore Figure 3 shows the measured roughness of the micro milling experiments. The smallest arithmetical mean deviation Ra could be reached by the use of tool group B with an average Ra = 208 nm. The mean roughness depth is between Rz = 1.3 µm and Rz = 1.9 µm and shows a bigger variance for tool group A.

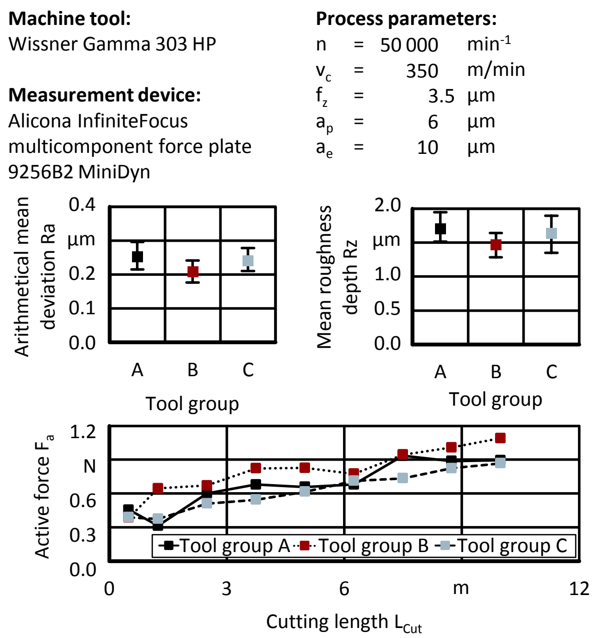

Figure 3. Active forces in the milling process and mean roughness of the workpiece

4. Conclusion

A reason for a short tool life of micro milling tools is commonly premature tool wear. An approach to stabilize the cutting edge and to improve the wear behaviour is the defined cutting edge preparation by using the immersed tumbling.

Within this paper micro milling tools with a diameter of D = 0.2 mm made of cemented carbide were prepared and tested in milling experiments. It is shown that the micro milling tools can be prepared with the immersed tumbling process and cutting edge radii with $5\ \mu m \leq r_\beta \leq 7\ \mu m$ can be produced. Further a reduced fluctuation of the active force F_a by micro milling tools with prepared cutting edges is shown.

Further research activities are necessary for the preparation with different lapping medias to produce smaller cutting edge radii r_β with $2\ \mu m \leq r_\beta \leq 5\ \mu m$ with a reduced chipping of the edge R_S. Also the process parameter of the immersed tumbling process should be analysed for micro milling tools with a diameter of D = 0.2 mm and the tool life has to be examined.

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