

Approaches to Enhance Surface Integrity in Turning of Aluminium Matrix Composites

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Abstract

Aluminium matrix composites are innovative lightweight construction materials, which usually consist of a relatively soft and ductile matrix and a hard ceramic reinforcing component. The high hardness of the reinforcing component results in extensively increased cutting tool wear by abrasion as well as defects of the machined surface in the form of voids and scaling. In this study, turning tests were conducted on Al₂O₃ particle-reinforced aluminium to evaluate the effect of tool edge geometry on cutting performance and surface integrity. These investigations have shown a significant reduction of the roughness and surface defects using tools with appropriate rake geometries.

1 Introduction

Increasing requirements on components during service often cannot be met by homogeneous materials. An alternative is the use of composite materials which enable tailored performance characteristics by a specific choice and proportion of their constituents. The key benefits of particle-reinforced aluminium matrix composites in comparison to the base alloy are superior strength, fatigue resistance, hardness, Young's modulus and wear resistance. These advantages, however, are realized at the expense of machinability. One problem is the creation of surface defects by the interaction of the hard particles and the matrix during cutting. Several particles are crushed and others ripped out of the matrix by the tool and leave surface flaws which may become initial points of microcrack formation under fatigue loading. Consequently, it is essential to improve the cutting process to obtain the required machined surface structure.

2 Experimental

The metal matrix composite used in the machining tests was comprised of a matrix similar in composition to AA2017 and 5 % volume proportion of Al_2O_3 particles with a size distribution in the range of 5 to 25 μm . This material was produced by powder metallurgy. The components were mixed, followed by cold isostatic pressing and extrusion. Afterwards, the bars had a diameter of approximately 17 mm. The material was heat treated to condition T4. Figure 1 shows the microstructure of the composite. The experiments were done on a SPINNER precision lathe with an integrated force dynamometer (Figure 2). The specimens with a length of approximately 20 mm and a diameter of 15 mm were OD turned between centers. The cutting trials were performed with parameters typical for finishing under application of cooling lubricant (emulsion). The depth of cut $a_p = 0.5$ mm and the cutting velocity $v_c = 150$ m/min were kept constant whereas the feed was varied between 0.05 and 0.15 mm.

In the machining tests, rhombic inserts of the type CCMW and CCGT 09T308 with a corner angle of 80° , clearance angle of 7° and a nose radius of 0.8 mm were used. The inserts are tipped with CVD diamond in order to withstand the intense abrasive effect of the ceramic particles and to generate high quality surfaces. The tools tested differ in their rake geometry (Figure 3). One insert has a plane rake (Tool 1) and two types of inserts have chip breakers (tools 2 and 3). The chip breakers differ in their geometry and dimensions. The rake angles adjacent to the cutting edge are 0° for all tools and in the region of the chip breaker they are about 17° to 18° . Furthermore, the wear of the tools is a significant factor of the cutting process. The flank-wear land width of the inserts with chip breaker during machining is in the range of approximately 30 to 60 μm whereas the wear of the plane rake insert with 70 to 80 μm is somewhat larger.



Figure 1: Microstructure of the composite

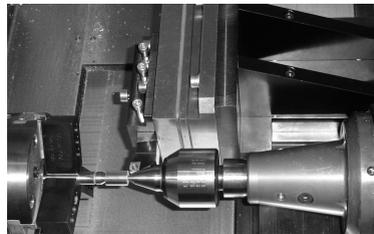


Figure 2: Trial equipment

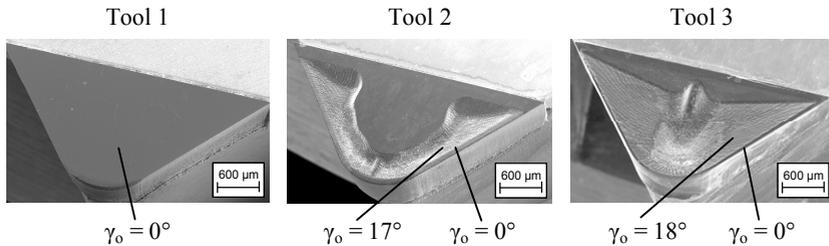


Figure 3: Rake geometry of the inserts

3 Results and discussion

The integration of chip breakers aims at a modification of the stress condition in the shear plane and a direction change of the chip flow. The determined influence of the tool geometry on the surface characteristics and the cutting forces is represented.

Figure 4 shows that workpiece surface roughness increased for all inserts with rising feed rates. Tool 2 generated higher surface roughness than Tool 1 (plane rake) for the same process parameters. Machining with Tool 3 allowed considerable reduction of the roughness. SEM micrographs of the generated surfaces were made to characterize their structure (Figure 6). The surface generated with the plane rake insert is relatively smooth and has minimal defects caused by particles which were pulled out. However, Tool 2 produced surfaces with clearly observable feed marks and material deposition as well as pores. Machining with Tool 3 yielded very smooth and almost flawless surfaces. A chip shape analysis enables to identify the reasons for the different surface roughness. When machining with Tool 1, the tool without any chip breaker, snarl chips were generated which caused slight flaws on the surface of the specimens. In turning with cutting inserts with integrated chip breaker (tools 2 and 3) long helical chips were formed for both tools, but the diameter of the chip helix in cutting with Tool 3 is approximately half as great as the helix diameter generated with Tool 2. This indicates that the small chip breaker of Tool 2 impeded the chip flow, which had negative retroactive effects on the surface. The positive rake angle in combination with a wide chip breaker (Tool 3) ensured a good chip flow and consequently improved the surface roughness.

Figure 5 illustrates the cutting forces for a feed rate of 0.1 mm. The cutting force in cutting speed direction is always the largest component irrespective of the tool used. Machining with Tool 2 resulted in higher forces than Tool 3 and the generated

surface roughness showed the same trend. An exception is the comparatively low roughness when using the plane rake tool despite of the high forces observed. The reason for this result is the larger flank-wear land width of the insert. It can be concluded that the measured force provides an indication of roughness from different tools with chip breaker under the same conditions. The results for Tool 3 are in agreement with Uhlmann's study [1] regarding the positive effect of chip breakers in PCD tools on surface roughness. In contrast to this study CVD diamond tools were suitable and did not fail due to large break-outs.

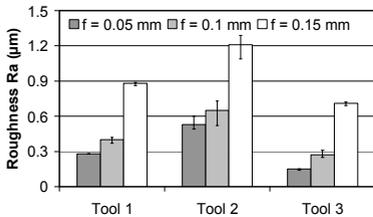


Figure 4: Influence of rake geometry on surface roughness

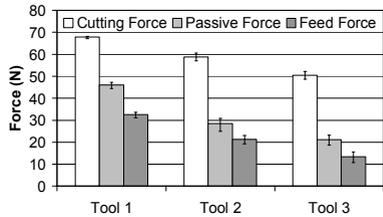


Figure 5: Influence of rake geometry on cutting force (f = 0.1 mm)

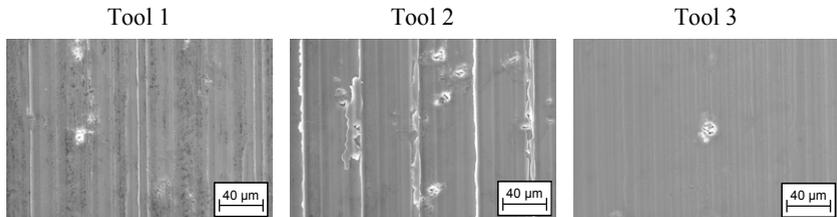


Figure 6: Influence of the rake geometry on the surface (f = 0.05 mm)

Acknowledgement

The authors acknowledge the DFG (German research funding organisation) for supporting this work carried out within the framework of Project SFB 692.

Reference:

- [1] Uhlmann, E.; König, J.: Machining of Al-MMC with Diamond Tools. 1st International Industrial Diamond Conference, October 2005, Barcelona, Spain