Reduction of Surface Imperfections in Turning of Aluminium Matrix Composites by an Appropriate Cutting Edge Design

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Abstract

In the majority of cases, aluminium matrix composites (AMCs) consist of a relatively ductile matrix and hard ceramic particles embedded therein. In addition to an increased tool wear, machining of these materials involves surface imperfections like voids and scaling. An approach to reduce the generation of suchlike imperfections is a modification of the cutting edge geometry. Turning tests have shown that smooth surfaces can be generated by using natural diamond tipped tools with a very small clearance angle of approximately 0.5° and a minor feed of 0.05 mm.

1 Introduction

Particle reinforced aluminium matrix composites are light weight construction materials with tailored properties characterized by a prior static and fatigue strength, Young's modulus and wear resistance in comparison to the parent alloy. Despite of improved master and metal forming processes, further machining of the components is usually indispensable. Cutting of such materials leads to surface imperfections like voids and cracked particles [1]. But, it is well-known that surface properties have a marked influence on the fatigue strength [2]. Consequently, smooth surfaces without any appreciable imperfections are beneficial for dynamically loaded components. An interesting aspect is that an increasing width of flank wear land leads to a reduction of the number and size of voids [3]. Hence, a similar effect has to be generated by a cutting edge modification for machining with new tools. An opportunity is a specific chamfering of the flank face producing high-quality surfaces.

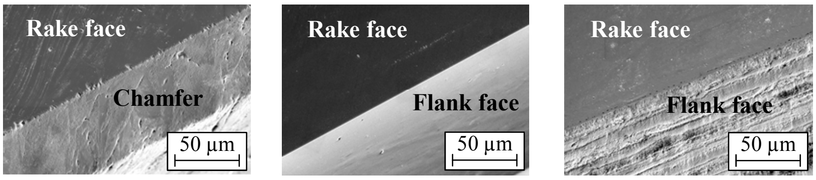
2 Experiment

The used aluminium matrix composite consists of an aluminium alloy AA2124 and SiC particles with a volume proportion of 25 % and an average size of two to three microns. This material is manufactured through a powder metallurgy route using a high energy mixing process. The powder is compacted by hot isostatic pressing and a subsequent extrusion technique. In order to increase the strength, the material is heat treated to the condition T4. Specimens used for the tests have a diameter of 25 mm and are 20 mm long.

Research in OD turning of the AMC was done on a SPINNER precision lathe. The specimens were clamped with a mandrel in order to machine their complete length. An oil-in-water emulsion with a concentration of about 5 % was applicated to reduce built-up edge formation on the rake face. The depth of cut $a_p = 0.5$ mm and the cutting speed $v_c = 200$ m/min were kept constant whereas feed was varied between 0.05 mm and 0.15 mm. The surfaces of the specimens were analyzed by roughness measurement and SEM.

For the experiments, rhombic inserts of the type CCGW 09T304 with a tool included angle of 80° and a corner radius of 0.4 mm were used. The cutting edge angle of the inserts was 95°. Because of the highly abrasive effect of the silica particles, inserts with diamond tips were chosen. For a reproduction of a mean wear condition, CVD diamond tipped tools were chamfered at the flank face involving a negative effective clearance angle, which was varied between -25° and -5°. The chamfer at the flank face had a land width of approximately 70 µm, but the size of the chamfer was not uniform for the complete cutting edge in consequence of tolerances during tool manufacturing. For comparative purposes, a CVD diamond tipped inserts without chamfer was utilised.

Another approach is the application of a tool designed for the generation of mirror-like surfaces. For that purpose, an insert with a single crystal natural diamond tip offering a clearance angle of about 0.5° on a land width of circa 220 µm was tested. Figure 1 represents the cutting edges for CVD diamond and natural diamond tipped tools.



Chamfered CVD diamond *Natural diamond, sharp* *CVD diamond, sharp*

Figure 1: SEM micrographs of the cutting edges of the diamond tipped inserts

3 Results and discussion

The influence of the micro geometry of the cutting edge and the feed is represented in Figure 2. The basic bars illustrate the average values of in each case three specimens and the small bars show the range of dispersion of the test results.

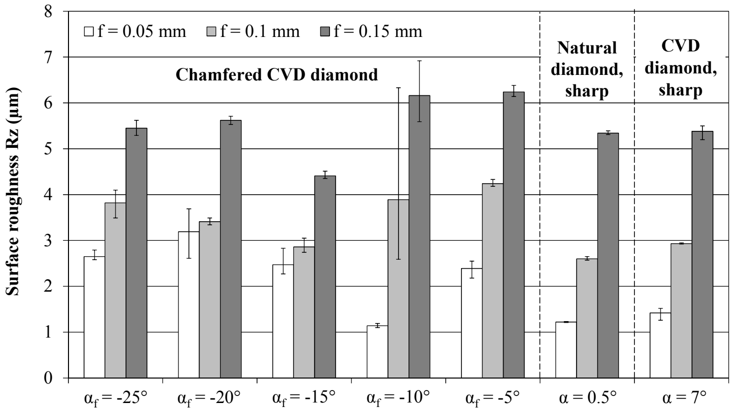


Figure 2: Influence of the cutting edge geometry and feed on the surface roughness

This diagram reveals that surface roughness values increased with increasing feed. But, for a feed of 0.05 mm there are very large differences between the single bars. These results can be explained by means of SEM micrographs of the surfaces (examples in Figure 3). In machining of AMCs with a commercially available and sharp (unworn) CVD diamond tipped insert, a macroscopically regular surface is generated. Consequently, the roughness values are low, but the surface exhibits many small voids, which do not raise the roughness values markedly. An approach for closing these voids is the use of chamfered inserts. For a clearance angle of the chamfer in the range of -25° to -15°, surfaces are characterized by distinctive scaling increasing the roughness values. The use of an insert with a clearance angle of the chamfer of -10° led to a comparatively smooth surface explaining the low roughness values. The surface is suggestive of a compression of the material involving less voids. A change of the clearance angle of the chamfer to -5° brought very smooth surfaces without appreciable voids about, but the feed marks showed a significant burr formation due to a high material compression rising the roughness values. This effect can sometimes be observed for turning with an insert with a clearance angle of the chamfer of -10° and a feed of 0.1 mm, which caused a very high range of dispersion of the roughness values. Best surface quality was reached when using the natural diamond tipped insert with a clearance angle of 0.5°. The polishing effect of the material on the flank face results in very smooth surfaces without distinctive voids or burr formation. Consequently, this geometry is particularly appropriate for advanced machining of particle reinforced AMCs generating high quality surfaces.

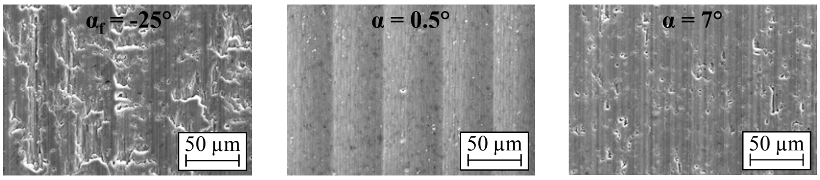


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Figure 3: SEM micrographs of the surfaces of the specimens (f = 0.05 mm)

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References:

[1] El-Gallab, M; Sklad, M.: Machining of Al/siC particulate metal matrix composites. Part II: Workpiece surface integrity. Journal of Materials Processing Technology 83 (1998), pp. 277-285

[2] Shazad, M. A.: Analysis of the Machinability of an Aluminium Matrix Composite Material. Produktionstechnische Berichte aus dem FBK. Doctoral thesis. Kaiserslautern: University of Kaiserslautern, 2010, pp. 91-99

[3] Schubert, A.; Nestler, A.: Enhancement of Surface Integrity in Turning of Particle Reinforced Aluminium Matrix Composites by Tool Design. Procedia Engineering 19 (2011), pp. 300-305