New PCD tools for micro machining

E. Uhlmann[1,2], A. Löwenstein[1], F. Mahr[2], M. Langmack[2]
1 Fraunhofer Institute for Production Systems and Design Technology (IPK), Germany
2 Institute for Machine Tools and Factory Management, Technische Universität Berlin, Germany

armin.loewenstein@ipk.fraunhofer.de

Abstract

A new tool concept for high precision milling, using polycrystalline diamond (PCD) as full cutting edge material, has been developed at Fraunhofer IPK. This paper gives detailed information on the tool concept, the production of the PCD tools and the results of first milling tests.

Introduction

Micro milling is a manufacturing process which has a high flexibility with regard to machinable materials and workpiece shapes. The process accuracy and reliability is, in addition to the characteristics of the machine tool, significantly depending on the properties of the cutting tool [1]. Nowadays most of the cutting tools for micro milling operations are made of cemented carbide. Due to fast growing tool wear and random tool breakage, micro milling operations are limited regarding accuracy and process reliability. Additionally, the process is limited by the hardness of the tool material which defines the range of machinable materials [2].

1 New PCD tool concept

The advantage of the concept, using polycrystalline diamond (PCD) as full cutting edge material, is the increased hardness of the cutting edge material in comparison to cemented carbide tools. The new tools have a shank made of cemented carbide and a soldered tool tip with a solid PCD disk. The PCD cutting edge is produced by wire electrical discharge machining (WEDM). The PCD disk has a thickness of $h_{PCD} = 0.5$ mm, a diameter of $D_D = 3.1$ mm, and a total height of $h_D = 1.6$ mm including the cemented carbide part. The shank is made of cemented carbide with a length of $l_S = 45$ mm, and a height of $d_S = 3$ mm. The PCD disk and the tool shank are joined by soldering with an operating temperature of t_O = 800 °C, a warm up time of t_W = 2 s, an effective soldering time of t_{eff} = 2 s, and a cooling time of t_W = 2 s.

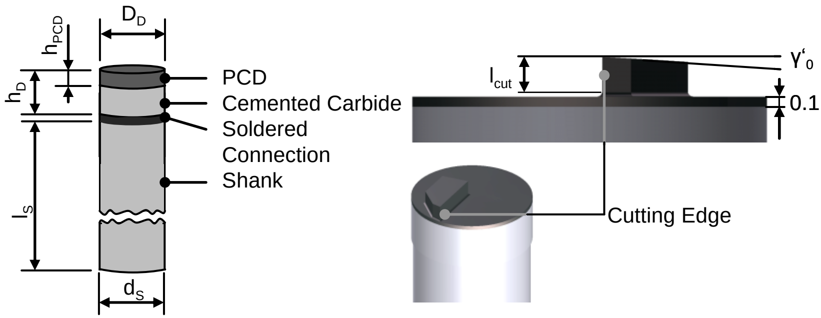

Figure 1: PCD tool design

2 Cutting test

In preliminary milling tests a prototype of the new PCD tools was compared to a conventional single flute end mill for aluminium cutting. This tool was made out of cemented carbide. The criteria for comparison were the forces in the working plane, the tool wear and the roughness of the machined surfaces.

2.1 Forces in the working plane

Figure 2 shows the progression of the forces in dependence of the cutting length L_{cut}.

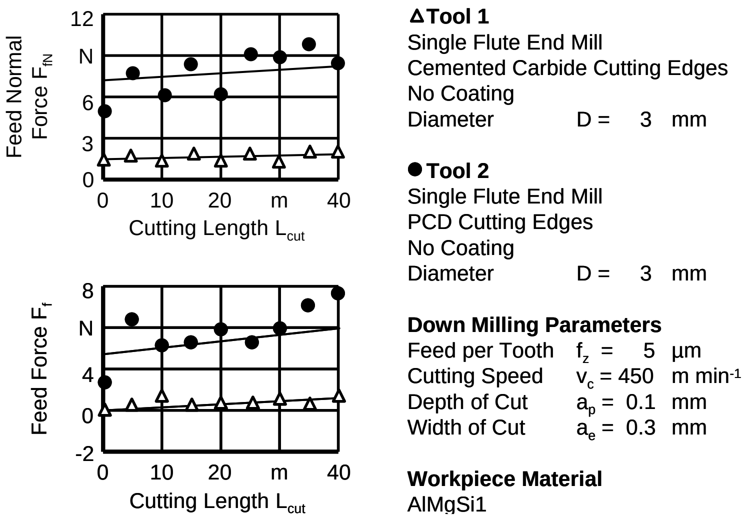

Figure 2: Forces in the working plane in dependence of the cutting length L_{cut}

For the data acquisition a Kistler MiniDyn 9256C2 piezoelectric dynamometer was used. The PCD tool (Tool 2) shows significant higher forces in comparison to the cemented carbide tool (Tool 1). The rake angle of the PCD tool is $\gamma = 1°$. The rake angle of the cemented carbide tool (Tool 1) is $\gamma = 13°$. That geometrical difference is most probably the reason for the force distinctions.

2.2 Tool wear

Figure 3 shows the wear of the tools in dependence of the cutting length L_{cut}.

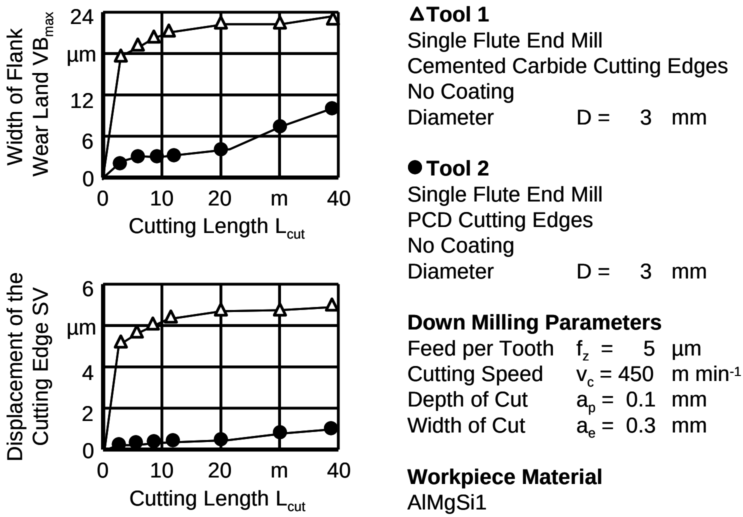

Figure 3: Tool wear in dependence of the cutting length L_{cut}

For the optical wear assessment a µEye UI-1480RE-C-HQ CCD camera with a Pentax H1214-M C-mount lens camera equipped with a diode ring light was used. As a result of the higher hardness of the PCD cutting edges the tool wear has been decreased strongly in spite of the higher active forces.

2.3 Surface quality

Figure 4 shows the surface roughness in dependence of the cutting length L_{cut}. For the surface characterization the mean values of three roughness measurements, detected by an optical system Alicona InfiniteFocus, were evaluated. The quality of the surfaces, which were machined by conventional cemented carbide tool, were irregular in comparison to the surfaces that were machined by the PCD tool. The reasons for the consistent results of the PCD tool could be caused by stable cutting edge conditions and the geometry of the PCD tool, which benefits the chip removal.

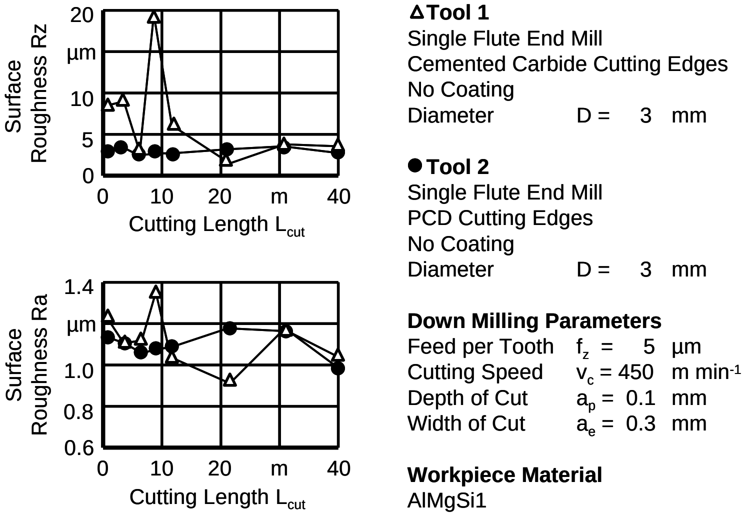

Figure 4: Surface roughness in dependence of the cutting length L_{cut}

Summary

The first PCD tool shows significantly better results regarding the tool wear behaviour and the quality of the machined surfaces in spite of the higher detected active forces. The first feasibility tests with the PCD tool show high potential for further research activities regarding the production and geometrical optimization.

References:

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[2] Uhlmann, E.; Mahr, F.; Loewenstein, A.; Raue, N.; Oberschmidt, D.: Performance Characteristics of Coated Micro Milling Tools. 9th "THE-A" Coatings in Manufacturing Conference. 3 – 5 October 2011, Thessalonica, Greece.