Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 45 (2016) 115 – 118

www.elsevier.com/locate/procedia

3rd CIRP Conference on Surface Integrity (CIRP CSI)

Investigation of Chip Formation and Surface Integrity when micro-cutting cp-Titanium with ultra-fine grain cemented carbide

F. Schneider[a] *, R. Bischof[b], B. Kirsch[a], C. Kuhn[b], R. Müller[b], J.C. Aurich[a]

[a]*University of Kaiserslautern, Institute for Manufacturing Technology and Production Systems, Gottlieb-Daimler-Str., 67663 Kaiserslautern*

[b]*University of Kaiserslautern, Institute for Applied Mechanics, Gottlieb-Daimler-Str., 67663 Kaiserslautern*

* Corresponding author. Tel.: 49-631-205-2868; fax: +49-631-205-3238. *E-mail address: frank.schneider@mv.uni-kl.de*

Abstract

The microstructuring of component surfaces via micro-cutting processes (e.g. micro milling) are adequate techniques for tribological or medical applications. Compared to conventional cutting processes, size effects influencing the chip formation and as a consequence the surface integrity arise. Those are for instance the ploughing effect or the growing influence of the cutting edge with decreasing depth of cut. In this research, the chip formation of cp-Titanium when micro-cutting in an orthogonal micro-cutting process is investigated. Ultra-fine grain cemented carbide cutting tools were used in quick-stop tests. The results show the coherences between the chip formation and the surface integrity.

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)

Keywords: Micro-cutting; Surface Integrity; Chip Formation

1. Introduction

Microstructured surfaces have great potential in improving tribological properties [1] as well as for influencing the cell adhesion in biological and medical applications [2]. Due to its durability and biocompatibility, Titanium is applied in different medical applications such as heart valves or pacemakers [3]. Micro-cutting processes provide adequate techniques due to the flexibility regarding the possible geometries and the comparably high material removal rates [4].

In micromachining, the influence of the microstructure of the workpiece material [5] and the growing influence of the cutting edge microgeometry [6] with smaller uncut chip thicknesses are much more pronounced than in conventional machining. Vollertsen et al. summarize these effects under the generic term size effects [7]

The investigation of the influence of size effects on the resulting workpiece surface and thus the surface integrity are a focal point of research activities in the field of micro-cutting. Weule [5] investigated the influence of the workpiece microstructure on the resulting surface when fly-cutting steel (SAE 1045). It can be seen that the ferrite springs back after machining and influences the surface as a result of elastic deformations. Finite element investigations on the size effects resulting from the cutting edge radius were carried out by Childs [6]. The results reval that the increase of the cutting edge radius at constant uncut chip thickness has a great influence on the chip formation mechanisms and therefore on the resulting process forces.

Compared to other methods such as for example the “Direct to SEM Method” [8] the so-called quick-stop method is a cost-effective and fast method for the study of the chip formation. In this tests the chip formation process is suddenly interrupted by means of quick-stop devices [9].

Most investigations on the chip formation and the surface integrity on the aforementioned Titanium focused on conventional cutting and titanium alloys [10]. Experimental investigations of the influence of the rake angle on the chip formation and the resulting surface integrity in the investigated scale with ultra-fine cemented carbide tools are not known.

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)
doi:10.1016/j.procir.2016.02.257

The aim of this paper is to show the influence of the rake angle when micro-cutting cp-titanium with tools made of ultra-fine cemented carbide. Tools with different rake angles were manufactured and applied in experimental studies. In this paper only the surface topography is analysed due to the fact that the surface topography is the target value in micro cutting.

2. Experimental Setup

The manufacturing of the tools used in this investigation as well as the experimental tests were conducted applying the ultra-precision turning lathe MTC 250 from LT Ultra.

2.1. Tool manufacturing

For the tool manufacturing a self-developed grinding unit was used (Figure 1) fixed on the x-carriage of the ultra-precision turning lathe. The tool blank (Ø 3mm) was fixed on the air bearing spindle via a clamping device. This allows to twist the tool to manufacture the designated tool geometry as illustrated in Figure 1. The tool material used was an ultra-fine grain cemented carbide with 92% tungsten carbide and 8% cobalt and an average grain size of 0.3 µm to achieve a very sharp cutting edge. For the grinding process a thin resin bonded diamond grinding blade (# 800) mounted on a hydrodynamic spindle was applied.

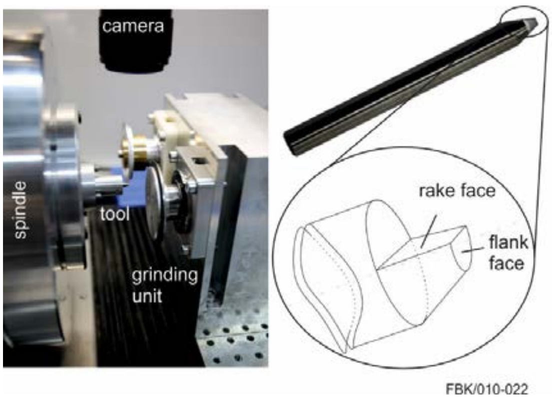

Fig. 1: Setup of tool manufacturing and tool geometry

The tool manufacturing was divided into three main steps. In the first step the cylindrical blank was provided with a peak of 40° cone angle. In the succeeding two main steps the flank face and the rake face were prepared.

Table 1: Tool geometry

Tool geometry	T_1	T_2	T_3
rake angle γ in °	0	10	20
tool orthogonal clearance α in °	10	10	10

To investigate the influence of the rake angle on chip formation and surface integrity three different angles were utilized. The geometry of the applied tools can be found in Table 1. Scanning electron microscope images of a manufactured tool with a rake angle of 0° are shown in Figure 2. Investigations of polished cross-sections of the tool show a very sharp cutting edge with a cutting edge radii < 300 nm.

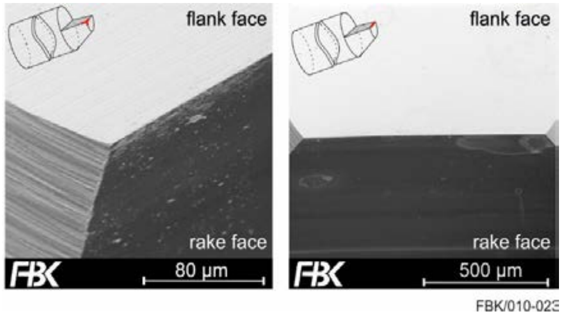

Fig. 2: SEM Images of manufactured tools with a rake angle of 0°

2.2. Cutting and Quick-Stop experiments

The experiments were carried out using a crystalline commercial pure (cp-) titanium bar (grade 2). As illustrated in Figure 3 on the right-hand side, ridges with a width of 100 µm were manufactured with a distance of 2,500 µm between each ridge. To minimize the influence of kinematics on the chip formation, orthogonal cutting experiments were conducted. The process forces were measured with a three axis force dynamometer.

Besides the rake angle the uncut chip thickness (in case of orthogonal cutting equivalent to the depth of cut) was varied in this series of experiments. A low cutting speed was chosen as those are low in micro-cutting processes as micro-milling and due to the limitation of the quick-stop-device. To investigate the influence of the uncut chip thickness three different uncut chip thicknesses are investigated. Furthermore the experiments were carried out without the use of a cutting fluid. The selected parameters are listed in Table 2.

Table 2: Cutting parameters

Cutting parameters			
cutting speed in m/min		1.10	
uncut chip thickness in µm	0.40	5.20	10

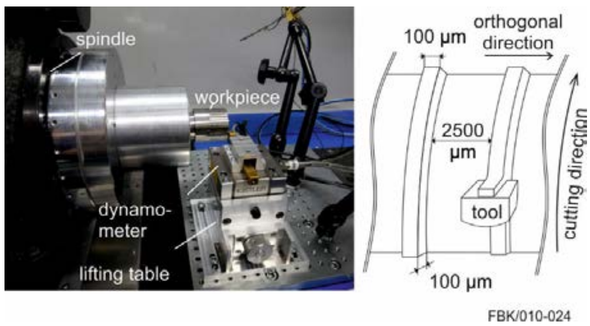

Fig. 3: Experimental Setup

To investigate the chip formation a self-developed quick-stop device was used [9]. The quick-stop device allows to