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Effects of different cutting edge preparation methods on micro milling performance

E. Uhlmann[a,b], D. Oberschmidt[b], Y. Kuche[a], A. Löwenstein[b], I. Winker[a]*

[a]*Institute for Machine Tools and Factory Management (IWF), Technische Universität Berlin, Pascalstraße 8-9, 10587 Berlin, Germany*
[b]*Fraunhofer Institute for Production Systems and Design Technology (IPK), Pascalstraße 8-9, 10587 Berlin, Germany*

* Corresponding author. Tel.: +49 30 39006 438. *E-mail address:* winker@iwf.tu-berlin.de

Abstract

In micro milling, which is mostly used in mold and die making, process reliability and predictability of tool failure are important. Particularly in precision and micro machining, tool breakage is hardly detectable and the requirements on accuracy are very high. Immersed tumbling is an appropriate process for the defined cutting edge preparation of micro milling tools. Its effects like increasing tool wear performance and tool life has been evaluated. In this paper, different cutting edge preparation processes showed that in cutting tests different effects occur regarding tool wear, process forces and surface quality. Immersed tumbling leads to the lowest active force F_a, but magnet finishing leads still do a slightly better surface quality.

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Keywords: Cutting edge preparation; micro milling, process reliability

1. Introduction

The use of micro milling tools with a diameter of $d \leq 1$ mm is widely spread in mold and die making. It is also applied in the direct production of parts in the micro range and the micro texturing of surfaces. Compared to macro milling, the tool diameter d and the chip thickness h is decreased, but it is not possible to decrease the rounded cutting edge radius r_β in the same scale. Therefore the ratio of the chip thickness to the rounded cutting edge radius h/r_β is decreased. Because of this effect, established technological parameters of macro milling are not directly transferable to micro milling [1]. The minimum chip thickness h_{min}, determined by the rounded cutting edge radius r_β, can surmount the chip thickness h, whereby elastic-plastic behavior begins to dominate the cutting process. This behavior is known as ploughing. The workpiece material is not longer sheared off by the cutting edge, but partially or completely pushed into the newly formed workpiece surface beneath the tool [2]. The reason for ploughing is a negative tool orthogonal rake angle γ_0, which prevails when the chip thickness h is clearly within the dimension of the rounded cutting edge radius r_β [3].

Nomenclature

a_e	width of cut
a_p	depth of cut
d	tool diameter
F_a	active force
F_{pr}	process forces
F_z	resultant force
f_z	feed per tooth
h	chip thickness
h_{min}	minimum chip thickness
h_0	burr height
l_c	path length
Ra	arithmetical mean deviation
Rz	mean roughness depth
r_β	rounded cutting edge radius
v_c	cutting speed

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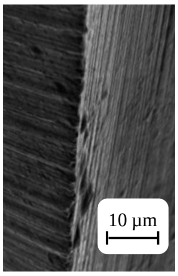
VB	width of flank wear land
z	number of teeth
γ_0	tool orthogonal rake angle

The tool grinding process usually produces an irregular cutting edge geometry. Thus in the subsequent milling process can be induced stress peaks inside the tool material which leads to edge breakouts or spalling of the coating. Tools can be finished with cutting edge preparation processes. These technologies can provide a rounded cutting edge radius r_β approaching the segment of a circle, which is constant over the cutting edge. The rounded cutting edge radius r_β should not rise too much to avoid ploughing [4, 5, 6, 7, 8]. This paper compares four of these processes: brush polishing, polish blasting, magnet finishing and immersed tumbling.

2. Cutting edge preparation processes

Brush polishing is classified as a cutting process, where the tool consists of bristle materials e.g. sisal, cord or synthetic fibre, attached to a rotationally symmetric brush form of tool holder [9]. The other technologies are classified as abrasive processes. Polish blasting is abrasive blast cutting with abrasive particles whose diameter is $d < 0{,}4$ mm. Magnet finishing is a technology, where ferromagnetic abrasive grains are attached to the face side of a rotating magnetic head. Due to the magnetic forces F_m the grains get tagged along with the magnetic head and the workpiece is held into them. For immersed tumbling, the workpiece is plunged with the kinematics of a planetary gear into a tank of abrasive material paste [10]. At the INSTITUTE FOR MACHINE TOOLS AND FACTORY MANAGEMENT IWF, tests have been conducted to the formation of cutting edge geometries, dependent on the cutting edge preparation process. The Fig. 1 shows the cutting edge of a micro milling tool, which was not machined with a cutting edge preparation technology [11].



No preparation
Workpiece:
micro milling tool
ultra-fine-grained carbid
d = 0.5 mm

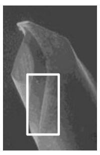
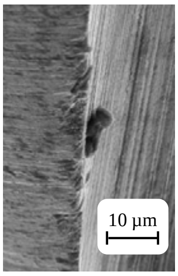
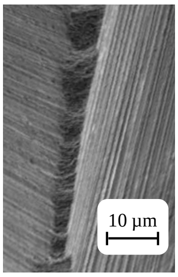


Fig. 1. micro milling tool
after final grinding with no additional edge preparation [11]

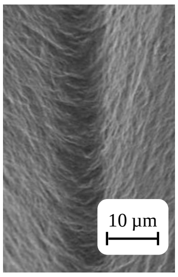
The Fig. 2 shows four micro milling tools of the same batch, prepared with the named cutting edge preparation processes. Brush polishing and polish blasting produce cutting edge cavities, particularly the latter one. It is more similar to a chamfer than a rounded cutting edge radius r_β. Magnet finishing and immersed tumbling, however, provide a constant rounded cutting edge radius r_β which fits basically the segment of a circle [11]. Tests at the IWF attest the micro milling tools, which are prepared with immersed tumbling, a reduction of the width of flank wear land *VB* by 14 % and a reduction of the variation of wear by 95 %, which allows to set closer limits for the time frame to replace the tool; a precondition for an economical use of the tools. Furthermore the active force F_a has less peaks, compared to tools with no preparation [5].



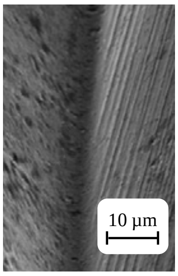
Brush polishing
Process parameters:
n_W = 0 1/min
n_B = 200 1/min
α_M = 45 °
t_M = 80 s
Bristle material:
horsehair with diamond paste



Polish blasting
Process parameters:
n_W = 20 1/min
s_b = 40 1/mm
α_M = 45 °
p_b = 0.3 N/mm²
t_M = 9 s
$d_{G,max}$ = 50 µm
Polishing medium:
glas beads of silicon dioxide



Magnet finishing
Process parameters:
n_W = 100 1/min
n_M = 200 1/min
α_M = 45 °
t_M = 6 s
$d_{G,min}$ = 40 µm
$d_{G,max}$ = 100 µm
Polishing medium:
BP 22 (abrasive material from Magnetfinish GmbH)



Immersed tumbling
Process parameters:
n_C = 200 1/min
n_R = 80 1/min
d_p = 70 mm
t_M = 60 s
$d_{G,min}$ = 400 µm
$d_{G,max}$ = 800 µm
Abrasive material paste:
H 4/400 (walnutshell-granulate with diamond paste)

Fig. 2. micro milling tools with different preparations [11]

Compared among themselves, magnet finishing and immersed tumbling lead to lower resultant forces F_z than brush polishing and polish blasting. The Fig. 3 shows the levels of the resultant forces F_z in line milling depending on the path length l_c. Magnet finishing and immersed tumbling also result in a lower tool wear. It is reduced by 9 % compared to brush polishing, and reduced by 14 % compared to polish blasting. The mean roughness depth *Rz* and the burr height h_0 are increased. Prepared with polish blasting, tools