Investigation of the resulting surface in ultra-precision turning of crystalline titanium

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Abstract

The aim of this paper is to investigate the resulting surface in ultra-precision turning of crystalline titanium in order to achieve a clearer understanding of the process in micrometric scale. Experiments were carried out using an ultra-precision turning lathe under orthogonal turning. Several separatored ridges with the width 100 µm, which is about the grain size of the used commercial pure titanium, were machined onto the sample to provide the orthogonal cut. To achieve a very small underformed chip thickness, mono crystalline diamond was used as cutting material.

1 Introduction and motivation

In several areas of application it is necessary to miniaturize components as well as to microstructure their surfaces. Therefore, suitable manufacturing technologies are needed. The ultra-precision cutting represents an adequate technology due to a high number of possible geometries and a high material removal rate. However, compared with conventional cutting processes, further effects had to be considered, such as the size effect between cutting edge and the depth of cut [1,2]. Furthermore, in crystalline materials the inhomogeneities caused by anisotropic properties and grain boundaries may influence the entire machining process [3,4]. In this article the influence of the cutting speed as well as the influence of the undeformed chip thickness on the surface is obtained for the case in which the grain size and the cutting width have similar sizes. In such a small scale the presence of grain boundaries and the effect of grain orientation are expected to become more evident in view of the cutting configuration adopted.

2 Orthogonal turning process

Experiments were conducted using an ultra-precision turning lathe under orthogonal turning process without coolant. The workpiece material was crystalline commercial pure titanium bar grade 2 with a diameter of 50 mm To accomplish the orthogonal cutting process seperatored ridges were prepared in several parallel sections of the sample, as shown in Figure 1. To carry out the experiements mono crystalline diamand tools were used to achieve the midget undeformed chip thicknesses. The well-known susceptibility to diffusion between titanium and carbon was neglected due to the low material removal level, for which only low temperatures are expected.

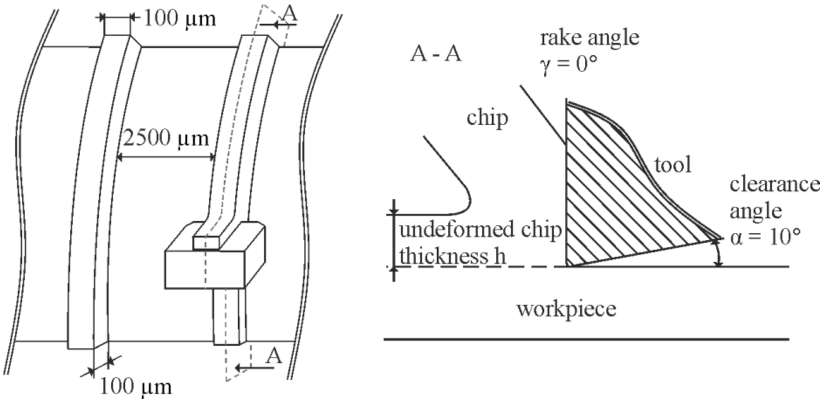


Figure 1: Geometric details

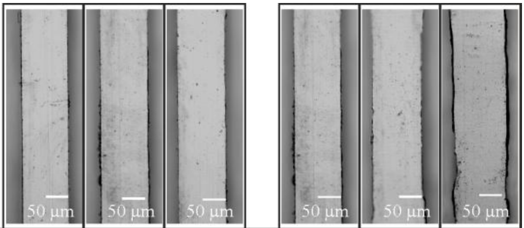
The cutting parameters are listed In Table 1. Nine cutting conditions were used to determine the influence of cutting speed and undeformed chip thickness on surface integrity of crystalline titanium.

Table 1: Cutting parameters

cutting speed	in	mm/s	26	79	131
undeformed chip thickness	in	µm	1	3	5

3 Results and discussion

At first, the surfaces generated by the experiments were observed by optical microscopy. The results show that the width of the ridges seems to have increased after the machining process (Figure 2). Furthermore, in addition to the bigger width of the ridge after cutting, the images show that with increasing uncut chip thickness the boarderline get more unsteady.



cutting speed v_c		mm/s	26	79	131	79	79	79
uncut chip thickness a_p		µm	1	1	1	1	3	5
burr height	$\bar{h}$	µm	3,0	3,0	3,7	3,0	4,0	12,7
	σ_h	µm	1,7	1,0	1,5	1,0	1,0	2,5

Figure 2: Machining Conditions

To investigate the boarder area, as well as the abovementioned increasing of the ridge width, metallographic cross-sections were taken and analysed. As seen in Figure 3, the apparent increasing of the ridge width is a consequence of resulting side burrs. This is a result of the fact that the material is deformed in front of the cutting edge [5]. Furthermore the results show that the burr height is influenced by the uncut chip thickness. With increasing chip thickness the burr high increases. An influence of the cutting speed can not be detected

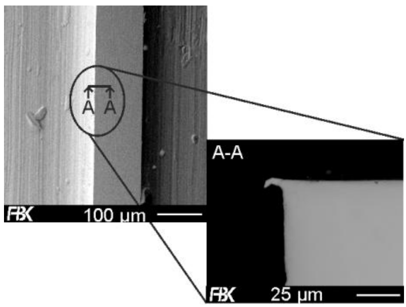


Figure 3: SEM (plan view) and microscopy images (cross-section) of the ridge border.

To investigate the surface topography, the ridges were analysed with a confocale microscope. As showed in Figure 4, five roughness profiles orthogonal to the tool path were analysed. No significant influence on the average roughness could be detected neither for the cutting speed nor for the undeformed chip thickness. This leads to the result that the diamond cutting edge is the major factor for the surface generation in lateral direction.

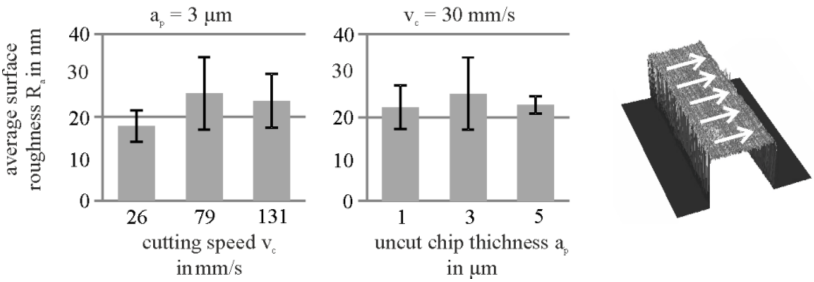


Figure 4: Influence of cutting speed and uncut chip thickness on lateral roughness

4 Conclusions

In this article orthogonal cuttings were carried out onto grain size rigdes of crystalline commercial pure titanium. The experiements show that the uncut chip thickness had the main influence on the side burr generated along the ridge boundary. An influence of the cutting speed on the surface roughness could not be detected. For the cutting speed of 30 mm/s the roughness transversal to the cutting direction was also unaffected by the undeformed chip thickness. This indicates that the cutting edge is the main influence in generating the surface.

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References

[1] D. Dornfeld, S. Min, Y. Takeuchi: Recent Advances in Mechanical Micromachining, CIRP Annals 55 (2006) 2, 745-768.
[2] C.-F. Wyen, K. Wegener: Influence of cutting edge radius on cutting forces in machining titanium, CIRP Annals 59 (2010) 1, 93-96.
[3] E. Uhlmann, S. Piltz, K. Schauer: Dynamische Werkzeuganalysen in der Mikro-zerspanung, Beurteilung des dynamischen Verhaltens von Mikrofräs-werkzeugen mit einem Einpunkt-Laservibrometer, wt Werkstattstechnik online 93 (2003) 3, 141-145.
[4] O. Riemer: Trennmechanismen und Oberflächenfeingestalt bei der Mikro-zerspanung kristalliner und amorpher Werkstoffe, Forschungsberichte aus der Stiftung Institut für Werkstofftechnik Bremen, 7 (2001).
[5] L. K. Gillespie, P. T. Blotter: The Formation and Properties of Machining Burrs, Trans. ASME, J. of Eng. for Industry (1976) 98, 66-74.