Precise Machining of Micro Dimples in Large Scale Areas

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Abstract

Machined micro dimples on surfaces are used for many applications, like friction reduction or information storage. For the unrestricted functionality of such surfaces, burr-free dimples are required. Therefore, the relations between the material properties, the tool tip micro geometry and the material separation have to be understood. In this paper the relevant chip and lateral burr formation mechanisms are discussed when machining steel surfaces by cemented carbide tools.

1 Introduction

The advantageous performance of micro-dimpled surfaces is mainly used in tribosystems. Here micro dimples can act as oil reservoirs, lead wear debris out of the contact zone or act as so called micro bearings by supporting the hydrodynamic floating of the conforming friction partner [1]. However, micro dimples have already found applications in data storage systems [2]. For the implementation of geometrically defined textures and dimples in large-scale areas cutting has proven to be very productive and flexible concerning dimple geometry [3]. Due to the small dimple dimensions size effects have to be considered with regard to the material properties [4]. For the unrestricted functionality of the described microstructure applications the machined dimples have to be free of burrs. However, this exhibits a challenge when machining steels by cemented carbide tools, which do not provide those sharp cutting edges like diamond tools. Preliminary investigations have shown that the tool cutting edge angle κ is one of the predominant impact factors on the lateral burr dimensions. In order to determine the relevant interrelations and mechanisms fly-cutting and quick-stop experiments have been carried out and evaluated.

2 Experimental setup

The experimental setups to investigate the burr formation mechanisms are shown in figure 1. The applied fly-cutting kinematics can be described as follows: By an axial movement of the spindle axis, the tool, mounted on a rotating tool body, is moved axially on a helical path along the worpiece surface. Thus, sickle shaped micro dimples are machined. Using the same kinematics a quick-stop device has been developed. Here the tool tip engages on a helical tool path as well. At the maximum depth of cut (centre of the dimple), a stopper, mounted behind the tool, accelerates the guided workpiece in cutting direction and interrupts the tool-engagement.

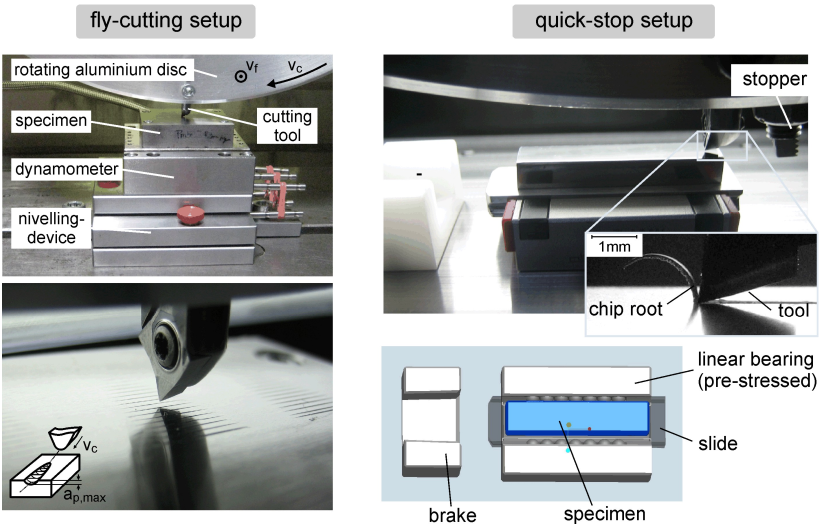

Figure 1: Fly-cutting and quick-stop setup

3 Chip and burr formation mechanisms

In order to identify the predominant mechanisms and the interconnections between chip and lateral burr formation, κ has been varied between 5°-90°. The lateral burr volume has been calculated to quantify the burr dimensions (figure 2).

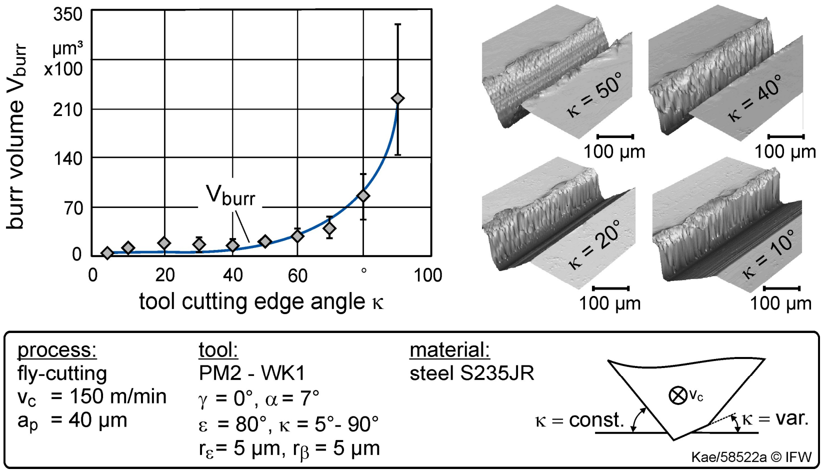

Figure 2: Impact of the tool cutting edge angle on the lateral burr dimensions

During the experiments the tool cutting edge angle has been kept constant at 50° on the left tool flank, while various angles have been ground on the right flank. Consequently the generated tool-tip profiles are not symmetric.

The fact that burr dimensions decrease degressively with decreasing tool cutting edge angle is due to the inhibition of material flow in the direction of the lateral free surfaces (due to a smaller deflection angle). Furthermore, the passive force causes thrust forces which are pointing orthogonally from the cutting edge to the workpiece material and thus determining the direction of material flow. The higher the tool cutting edge angle, the more the vector of this thrust force is shifted towards the lateral free surfaces and the higher the lateral burr dimensions.

The asymmetric cross-section of undeformed chip can be clearly extracted by the cross-section of the chips (figure 3). Analyses of the chips material microstructure show tendencies that the gradient of material deformation increases slightly with the cutting edge angle.

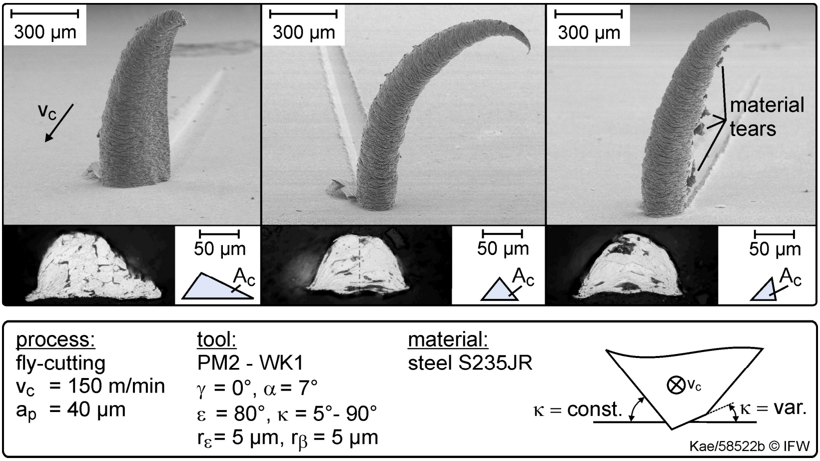

Figure 3: Impact of the cross-section of undeformed chip on the chip cross-section

The lateral burrs do not develop continuously. Here material in front of the tool-tip is periodically compressed and squeezed in the direction of the lateral free surfaces. Additionally lateral burr material is teared out by the chip-flow. The described effects intensify with increasing cutting edge angles. In order to overcome the undesirable burr dimensions at large tool cutting edge radii κ, positive tool cutting edge inclination λ_s orthogonal to the free surface have proven to counteract the development of burrs (figure 4).

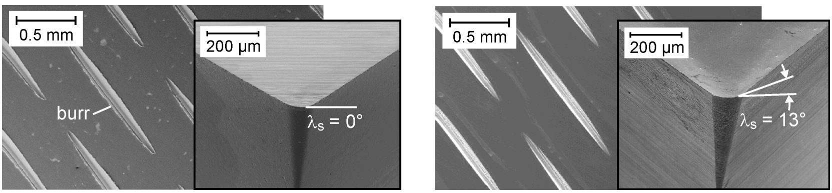

Figure 4: Reduction of burr dimensions by a positive tool cutting edge inclination λs

4 Conclusions

Within this paper the relevant chip and lateral burr formation mechanisms have been identified when machining micro dimples by fly-cutting kinematics with cemented carbide tools. The predominant relations between the tool cutting edge angle κ and the chip-/lateral burr formation has been identified. Here increasing lateral burr dimensions can be lead back to thrust forces and material flow in the direction of the lateral free surface areas as well as material deformation in the chip compression zone. To counteract the large burr dimensions with increasing tool cutting edge angle κ tool tip geometrys with positive cutting edge inclination λ_s orthogonal to the free surfaces have proven to be very successful.

5 Acknowledgements

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