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Influence of drilling depth and feed per tooth on burr formation when micro drilling

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Abstract

Micro drilling is a common process to manufacture micro holes. However, micro drilling is characterized by burr formation at the drill entry and exit. Deburring is not possible or only possible with great effort. For this reason, burr formation must be avoided or minimized by appropriate selection of the process parameters.
In this paper, the burr formation when micro drilling is investigated. Micro drilling tests were carried out using uncoated cemented carbide micro drills with a diameter of 100 µm. When machining brass, the drilled hole depth and feed per tooth were varied. Burr formation and manufacturing accuracy were analyzed. In particular, the burr height, the burr width, and the diameter-deviations of the hole were considered. The results are discussed and recommendations for micro drilling of brass are given to enhance the process efficiency and the functionality of the components.

Micro drilling, manufacturing accuracy, burr formation

1. Introduction

Micro drilling is widely used in industrial applications [1]. In many cases, the quality of the micro drilled holes determines the functionality of the components. Micro drilling is characterized by burr formation at the drill entry and exit [2]. Due to the high cutting edge radius r_β to chip thickness h ratio (r_β/h ratio), drilling with these tool sizes is characterized by squeezing and friction processes [3], which result in burr formation. Subsequent deburring is not possible or only possible with high efforts. This results in the need for knowledge of chip and burr formation as a function of the process influencing variables (e.g. cutting edge radius, chip thickness/feed per tooth) to reduce burr formation and finally increase the hole quality.

This paper focuses on the investigation of the influence of the parameters drilling hole depth and feed per tooth on the burr formation and the diameter of micro holes when using micro drills with a diameter of 100 µm.

2. Experiments

2.1. Experimental setup, tools, and workpiece material

The tool used for the micro drilling tests was a single edged uncoated micro drill made of cemented carbide with a diameter of 100 µm (manufacturer: Prestera[1]). The micro drill had a drill-point angle of 120°, a helix angle of 0° and a flute length of 700 µm. SEM images of the tool used is shown in Figure 1.

The micro drilling tests were carried out on the micro milling center (MMC), a desktop sized machine tool developed at the Institute for Manufacturing Technology and Production Systems at the RPTU Kaiserslautern. The air-bearing spindle (spindle speed range 10,000 rpm-125,000 rpm) has a maximum run-out of 2 µm at the applied spindle speed of 30,000 rpm.

The workpiece material used for the micro drilling experiments was brass (CuZn39Pb2) with a size of 10 mm x 20 mm x 3 mm. Prior to micro drilling, the workpiece was face milled with an end mill with a diameter of 3 mm.

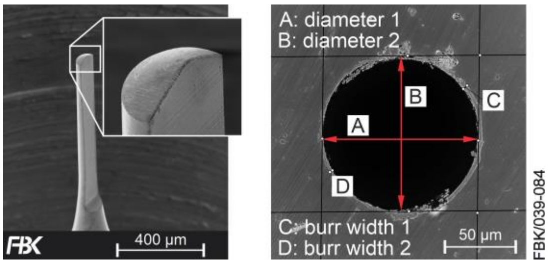

Figure 1. Micro drill with a diameter of 100 µm used for the experiments and exemplary evaluation of a drilled hole.

2.2. Cutting parameters

In the experiments the drilled hole depth and the feed per tooth were varied each at three levels: the drilled hole depths 50 µm, 100 µm, and 150 µm and the feed per tooths (f_z) of 0.05 µm, 0.5 µm, and 1 µm were considered. The spindle speed of 30,000 rpm was kept constant. Each parameter combination was repeated three times. The order of the tests was randomized. All tests were carried out with one tool. The tool was not unclamped during the experiment, which means that the influence of the clamping error on the run-out and therefore the effective diameter of the tool is constant. This allows to analyze the influence of the varied parameters on the burr formation and the diameter of the hole in the best possible way. Due to the in total very short feed travel, a significant influence of abrasive wear on the process results can be excluded.

2.3. Experimental procedure

First the spindle was warmed up for 10 minutes. The feed travel of the micro drill inside the workpiece is composed of the distance until the drill tip completely entered the workpiece and the drilling depth itself. The movement of the micro drill outside the workpiece was chosen sufficiently long to ensure that the acceleration of the axis is completed when the micro drill enters the workpiece.

2.4. Measurement technology

To analyze the burrs and the diameter of the drilled hole, confocal microscope images were taken using a Nanofocus[1]

OEM microscope. A 60x objective lens with a numerical aperture of 0.9 was used. The measuring field was 268 µm x 268 µm.

The width and height of the burrs and the diameter of the hole were analyzed using the software MountainsMap[1]. The diameter was measured in X- and Y-direction (see Figure 1). Out of these two values the mean value and the deviation to the nominal diameter of 100 µm was calculated. The burr height is the maximum burr height. The burr width, which represents the uniform bead around the drilled hole, was measured at two different points. As for the diameter, a mean value out of these two values was calculated.

3. Results and discussion

3.1. Burr height and width

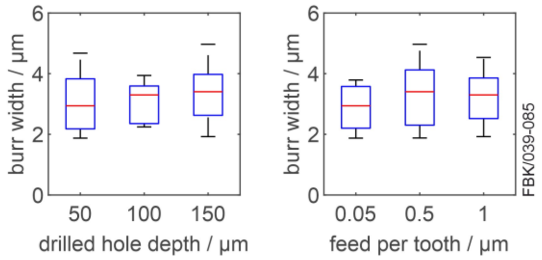

Figure 2. Burr width depending on drilled hole depth and feed per tooth.

Figure 2 shows that there is only a slight increase in burr width with increasing drilled hole depth. The median increases from 2.9 µm at a drilled hole depth of 50 µm to 3.4 µm at a drilled hole depth of 150 µm. However, the scatter of the measured values remains the same. The feed per tooth has no notable influence on the burr width.

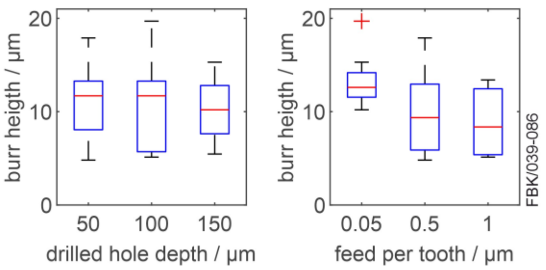

Figure 3. Burr height depending on drilled hole depth and feed per tooth.

Figure 3 shows that the drilled hole depth only has small influence on the maximum burr height. The median decreases from 11.7 µm (50 µm) to 10.2 µm (150 µm). However, a clear impact of the feed per tooth is recognizable in the burr height. The median of the maximum burr height decreases from 12.6 µm to 9.4 µm (f_z = 0.05 µm increased to 0.5 µm), which corresponds to a reduction of 25 %. At the same time, the scatter of the values has increased. Between 0.5 µm and 1 µm there was a further slight reduction in the median of the burr height. The reason for the reduction in burr height is probably the exceeding of the minimum chip thickness between a feed per tooth of 0.05 µm and 0.5 µm, which results into a better chip separation and less ploughing.

3.2 Diameter deviation

Figure 4 shows that there is an increase in the scatter of the measured values of the diameter deviation with increasing drilled hole depth. In contrast, the median stays at the same level (7.5 µm) from a depth of 50 µm to 100 µm and increases at 150 µm to 12.0 µm. In general, it can be observed that the measured diameters are higher than the nominal diameter of 100 µm. This deviation cannot be attributed to the run-out of the spindle.

As the drilling depth increases, more chips must be removed out of the hole. Since the tool has no helix, it is possible that the chips are not removed out of the hole sufficiently fast, resulting in squeezing processes on the circumference of the drill and increasing temperatures. This could lead to built-up edges resulting in an increase in the effective diameter.

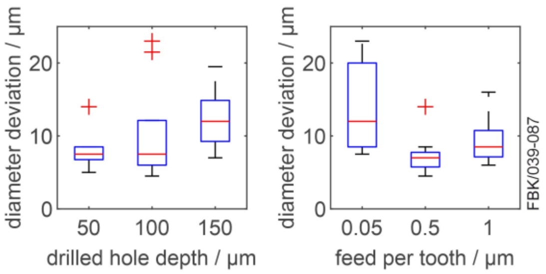

Figure 4. Diameter deviation depending on drilled hole depth and feed per tooth.

In contrast to the drilled hole depth, the scatter of the measured values of the diameter deviation decreases with increasing f_z. The lowest median with 7.0 µm was achieved with the central f_z of 0.5 µm. The highest median with 12.0 µm occurred at f_z = 0.05 µm. The reduction in diameter deviation is probably due to the lower amount of ploughing at 0.5 µm compared to 0.05 µm, which results in less adhering material at the tool. With a further increase of f_z to 1 µm, the chip cross-section is further increased, which leads to a higher load on the micro drill.

4. Conclusion and outlook

In this paper, micro drilling with a single-edged 100 µm diameter tool was examined. The focus was on burr formation and diameter deviations when machining brass. The drilled hole depth and the feed per tooth were varied each at three levels.

The results show that the drilled hole depth has no influence on the burr formation, but on the diameter variation. The feed per tooth has no influence on the burr width, but on the burr height. The diameter deviation was positively influenced by rising feed per tooth.

These first studies show that the hole quality in micro drilling can be improved by adjusting the drilling parameters. In further studies, the parameter field will be extended and also through-holes as well as drilling cycles will be examined.

Acknowledgements

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[1] "Naming of specific manufacturers is done solely for the sake of completeness and does not necessarily imply an endorsement of the named companies nor that the products are necessarily the best for the purpose."

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