A Study on Reduction of the Top Burr During Planing of Micro Channel Patterns

Tae-Jin Je[1], Eun-chae Jeon[1], Eun-Seok Park[1], Doo-Sun Choi[1], Kyung-Hyun Whang[1]
[1]*Dept. of Nano Manufacturing Technology, Korea Institute of Machinery & Materials (KIMM), Daejeon 305-343, South Korea*

jtj@kimm.re.kr

Abstract

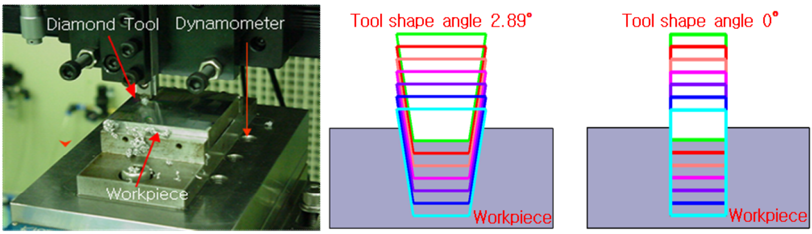
Cutting methods using ultra-fine planers/shapers are widely used to machine micro patterns on molds employed for manufacturing highly functional optical elements used in the LCD and LED industries. The top burr created during cutting, however, can deteriorate the quality of the micro pattern and the final product. In particular, the top burr becomes more severe in the case of machining micro channels having a high-aspect ratio. The present study investigates various means of reducing the top burr formed during planing. The parameters of tool shape angle, initial cutting depth, and overlapped cutting depth were investigated with respect to their effects on the creation of a top burr. The results of the study indicate that small tool shape angle and low cutting depth helped reduce the top burr, and the top burr formed in the first cutting step was proportional to the total top burr.

1 Introduction

Cutting methods using diamond tools are widely applied to manufacture products and metal molds having micro patterns. In particular, planers/shapers provide a powerful means of machining micro square channel arrays of several tens of micro meter width. However, a micro burr is created during cutting and this top burr is particular problematic when using a planer/shaper [1]. The problem of the top burr becomes more severe when machining a micro channel with a high aspect-ratio as it leads to overlapped cutting [2]. However, it is known that ultra-fine cutting methods suffer from problems related to the formation of a micro burr [3]. Shaping or planning methods employed for creating micro channels inevitably lead to the formation of a top burr. In particular, the top burr becomes more severe in the case of overlapped planing for micro channels having a high-aspect ratio [4]. The present work investigates methods of reducing the top burr formed during planing.

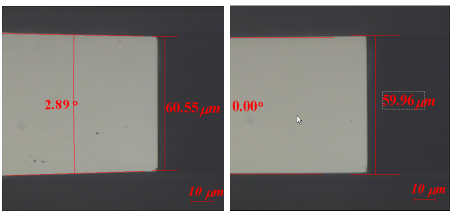
2 Machining system and machining method of micro channel

A machining system using a planer and a method of machining a micro channel are respectively displayed in Figure 1. The system can control three-axis movement with 5nm accuracy. The width of diamond tools for this study was 60µm and the tool shape angles were 2.89° and 0°, as shown in Figure 2. The cutting conditions are summarized in Table 1. First, four different micro channels, having 2, 4, 6, and 10µm cutting depth, were machined with the two diamond tools. Overlapped cutting at cutting depths of 4, 6, 8 and 12µm was then performed on a micro channel with 2µm cutting depth, which showed the smallest top burr.



(a) (b)

Figure 1: (a) Machining system having ultra-fine three-axis planer and (b) machining method



(a)W 60µm, A 2.89° (b)W 60µm, A 0°

Fig. 2: Diamond tool shape and angle

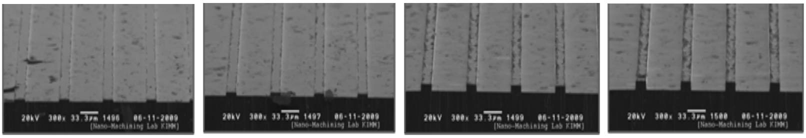
Table 1 Cutting conditions

Machine tool	**Planer (200×200 stroke)**
Cutting tool	**Diamond tool Width60 ㎛, θ=2.89°/ 0°**
Cutting speed	**1,200 ㎜/min**
Pattern size	**Pitch 80 ㎛**
Cutting depth	**2, 4, 6, 8, 10 ㎛**
Workpiece	**6:4 brass**
Cutting oil	**Mist oil No.9**

3 Machining results of micro channel and discussion

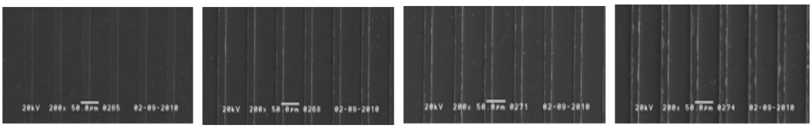
3.1 Effects of initial cutting depth on top burr

Photos of machined surfaces are presented in Figure 3. The top burr was more severe at micro channels with higher initial cutting depth, and this tendency was observed for both tool shape angles considered in this study. A larger top burr was observed in the case of machining with 2.89° tool shape angle than 0° at the same initial cutting depth. This indicates that the top burr may be created easily due to cutting force to the side direction even when the tool has a small tool shape angle.



depth 2μm depth 4μm depth 6μm depth 10μm

(a) tool shape angle = 2.89°



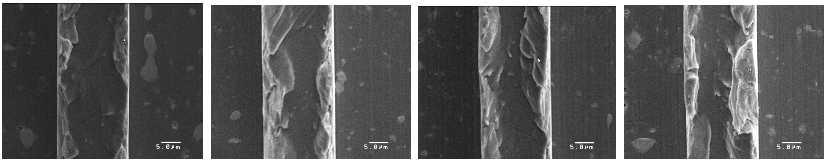
depth 2μm depth 4μm depth 6μm depth 10μm

(b) tool shape angle = 0°

Figure 3: Comparison of machining surfaces varied by initial cutting depth and tool shape angle

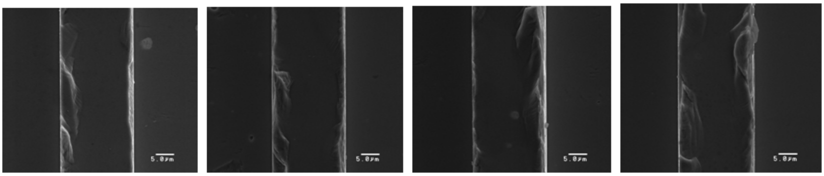
3.2 Effects of overlapped cutting depth on top burr

Figure 4 shows the machining results for four different micro channels, having 2, 4, 6 and 10μm overlapped cutting depth, on micro channels of 2μm initial cutting depth, which showed the smallest top burr. A larger top burr was observed at higher overlapped cutting depth in the case of 2.89° tool shape angle. This indicates that the initial top burr grows continuously with movement toward the side part during the overlapped machining. On the other hand, similar top burr was observed for all overlapped cutting depths in the case of 0° tool shape angle. This consistency in burr size is attributed to the absence of interference between the diamond tool and the top part of the micro channel. Based on the results, it was found that small tool shape angle and low cutting depth helped mitigate formation of the top burr. It will be possible to machine micro channels of high aspect-ratio with conditions of small tool shape angle and low cutting depth and thereby minimize the formation of a top burr.



depth 2+4 ㎛ depth 2+6 ㎛ depth 2+8 ㎛ depth 2+10 ㎛

(a) Tool shape angle = 2.89°



depth 2+4 ㎛ depth 2+6 ㎛ depth 2+8 ㎛ depth 2+10 ㎛

(b) Tool shape angle = 0°

Figure 4: Comparison of burr growth with different cutting depth

4 Conclusions

1. The top burr can be minimized by small initial cutting depth and zero tool shape angle.

2. It is important to reduce the initial top burr when machining micro channel of high aspect-ratio because the initial top burr is proportional to the final top burr.

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