BURR FORMATION IN MICRO-DRILLING
Boris Stirn\textsuperscript{1}, Kiha Lee\textsuperscript{2}, David A. Dornfeld\textsuperscript{2}

1. University of Technology at Aachen (RWTH), Aachen, Germany
2. University of California at Berkeley, Berkeley, CA

Key words: burr formation, micro-machining, micro-burr, micro-drilling

Abstract

Experimental studies on micro-drilling in aluminum alloy and steel have been carried out. Drilling experiments with different feed to diameter ratios, cutting speeds and 130µm, 250µm, 500µm drills were conducted. The influence of the cutting parameters on burr size and burr type was observed. A comparison to burr formation in conventional drilling is presented.

Introduction

Most machining processes produce burrs. These burrs cause several problems for product quality and functionality as they can interfere with assembly of parts or may reduce the fatigue life. Deburring of micro-structures is especially difficult due to bad accessibility and tight tolerances. In some cases, due to part fragility or edge tolerances, deburring of micro-parts is not possible. Therefore, reducing burr is very important in micro-machining. Understanding the burr formation and its dominant parameters is essential for predicting and reducing burr. Very few studies \cite{1} \cite{2} have been performed on the burrs resulting from micro-drilling. Micro-burr formation in aluminum alloy has been investigated with respect to cutting conditions \cite{2}. The fundamental mechanisms are not well understood.

Previous research \cite{3} had established basic burr types in the conventional drilling of low alloy steel. Burr shape is the most important because the burr size, and as a result, deburring cost is greatly dependent on it. Three different shapes of burrs were observed as seen in Figure 1. The uniform burr has relatively small and uniform burr height and thickness around the hole periphery. The crown burr has a larger and irregular height distribution around the hole. The transient burr is a type of burr formed in the transient stage between the uniform burr and the crown burr.

The work presented in this paper investigates the factors which significantly influence the burr formation process in micro-drilling. The burrs which result from micro-drilling in the different materials have been characterized and are compared to conventional drilling. Analysis of the data for the effect of diameter, cutting speed and feedrate and the mechanics of burr formation in micro-drilling are addressed. Burr shape of micro-burr is investigated.

Figure 1. Drilling burr types; (a) (b) uniform burr , (c) transient burr, (d) crown burr
Experimental setup

Drilling experiments in 6061-T6 aluminum and 25MoCrS4 steel (similar to AISI 4130) were conducted in 21 speed and feed variations, Table 1. The cutting parameters are based on recommendations by the tool manufacturer. Three different diameters, 130µm, 250µm, 500µm, are tested. Figure 2 shows 250µm drill and its cutting edge, of which radius is 3µm. A micro drill was attached to a Mori Seiki CNC Drilling Center TV-30 or Cameron Micro Drill Press MD-90. Micro-drop coolant was used. The height and thickness were measured using SEM pictures. Other current methods to measure burr size such as contact method, optical microscope method, etc, cannot easily apply to micro-burr due to small size. Measuring burr thickness is more difficult than height due to the irregularity of the shape using SEM. The measurements of the five holes were averaged for each cutting parameter.

![Figure 2. SEM of 250µm micro-drill (left) and its magnified cutting edge (right)](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Aluminum</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>130µm, 250µm, 500µm</td>
<td></td>
</tr>
<tr>
<td>feed/diameter</td>
<td>0.00625 – 0.1</td>
<td>0.005 – 0.08</td>
</tr>
<tr>
<td>feed/rev [µm]</td>
<td>0.81 – 50</td>
<td>0.65 – 40</td>
</tr>
<tr>
<td>RPM</td>
<td>6000 – 19500</td>
<td>4000 – 7600</td>
</tr>
<tr>
<td>Cutting speed [m/min]</td>
<td>2.5 – 30.6</td>
<td>1.6 – 11.9</td>
</tr>
</tbody>
</table>

Results

**Aluminum micro-burr**

A tendency of increasing height with increasing feed was observed, Figure 3. The effect of cutting speed is not clear. The burrs created by the 250 µm and 500 µm drill shows similar tendencies with respect to the feed rate. No large difference of burr height in 130 µm drill from one feed/diameter ratio to the next was observed compared to other two bigger drills. The comparison of the average burr heights at different drill sizes shows a minimum at 250 µm. The effect of speed is not consistent concerning burr thickness as both higher and lower speed creates a thicker burr. The values of burr thickness correspond to the values of height. Higher feed rate produces thicker burr.

Figure 4 shows micro-burr chart with the 250µm drill according to feedrate and speed. Micro-burr type is similar to conventional drilling. Uniform burr is observed only in the lower feed. No uniform burr cannot be seen in the 130µm drill. Again the effect of increasing feed is
confirmed as the formation mechanism changes to crown burr formation. No consistent effect of speed was observed.

**Steel micro-burr**

The burr height is a function of the feed as observed in the drilling of aluminum, Figure 5. Increasing feed has the effect of increasing height. With the 500µm drill, increases in speed also increases burr height, which increases from 37 µm at low speed to 52µm at medium speed. The value goes down slightly to 50 µm at high speed. In the case of the 250µm, the burr height at low speed (27 µm) is higher than at medium (17 µm) and high speed (18 µm). Using 130µm, the height at different speeds does not vary much. The feed shows the same effect on burr thickness that was observed on burr height. The cutting speed has no significant effect on the thickness.

The burrs at the lowest three feed rates show mostly uniform burr formation, Figure 6. With the highest feedrate the SEM shows very clearly a crown burr formation. In the second highest feedrate, the burr parts with crown characteristics and the big cap fragments indicate the transition between the uniform and the crown burr formation. No uniform burr was observed when the 130 µm drill was used.

---

**Figure 3. Burr height of aluminum in 130µm diameter (left) and 250µm diameter (right)**

**Figure 4. Burr shape chart of aluminum in diameter 250µm according to feedrate and speed.**
Acknowledgments

This work was supported by the Consortium on Deburring and Edge Finishing (CODEF) at University of California at Berkeley. Information is available at http://lma.berkeley.edu.

References