Geometry Verification of the Holes Obtained During Shear Cutting Process

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Abstract

The paper presents the method, which allows to measure geometry of the holes obtained in the cutting process. The measurements were carried out by means of a specially designed vision system with double illumination. This illumination enable simultaneous measurement of the hole’s diameter and rollover on its edge. The size of the measured rollover depends on clearance value occurring in the process. Results of the rollover measurement can be related to the clearance, which allows to estimating the quality of the obtained hole.

Keywords:
Shear Cutting; Rollover; Geometry Measurement; Vision System.

1. Introduction

Shear cutting is one of the sheet metal forming processes. It allows to obtain a flat product of any shape (blanking) or product with holes (piercing) with different dimensions and locations. Shear cutting is usually carried out by means of press, in which tools in the form of punch and die with sharp cutting edge are used.

One of the basic parameters of cutting process is the clearance, which is the difference between the radius of the hole in the cutting plate (die) and the radius of the punch (Fig. 1). Generally clearance is reference to the sheet thickness. The applied clearance determines the course of the punching process, influencing on the quality of the cutting surface and hole geometry [1-3]. As the clearance increases, the slope of the cutting surface in the slug and hole increases. At the same time, the burnish zone is reduced and fracture zone increased. Furthermore rollover area at the edge of the hole increases (Fig. 2). Rollover is one of the visible effects of the clearance value, and it could be directly measured in the final product.
During verification of the hole dimensions, not only determination of the internal diameter of the hole can be important, but also the quality of the hole cutting surface. This quality can be verified indirectly based on estimated clearance, which also influence on the size of rollover measured by means of the method proposed by the authors.

2. Geometry verification method

As previously mentioned, clearance value influence on the product geometry and the zones of the cutting hole surface, including the rollover width on the hole edge. Most of these parameters can be determined by means of microscopic measurements of the cutting hole surface or measurements by means of CMMs machine. Unfortunately, microscopic examinations are time consuming, which are practically impossible to carry out fast evaluation of the clearance and hinders their use in production conditions. The authors have proposed a method, which allows to fast measurement of the hole diameter and rollover area at the hole edge. Because increase in the clearance values causes increase of the rollover area [4, 5], therefore, it is possible to estimate the quality of the separation surface based on the rollover measurement. The proposed method is based on the measurement of the rollover area \( W_r \) (Fig. 3), which is the half of the difference between the external rollover area diameter \( d_r \) and the inner diameter of the hole \( d_i \). Because measurements are carried out in the sheet plane, there’s no need to perform cross-sections through the hole and it can be conducted on finished products. These parameters are measured by means of the vision system described in the following section.

3. Vision setup

The concept of measurement described in the previous chapter was implemented by means of a specially prepared vision system. Fig. 4a. shows the scheme of the experimental measurement setup.

a)
Basic components of the vision system are camera with lens (1), axial illuminator (2), backlight illuminator (3) and PC (4) analyzing an image of the sample (5). The backlight used in the measurements allows to highlight the shape of the hole (Fig. 4b) and thus measure its internal diameter.

In order to measure the rollover width, additional collimated axial lighting was used to illuminate the object from the rollover side. The basic feature of this light is to highlight any irregularities on the surface of a flat sheet. This allows to extract the rollover area on the edge of the hole (Fig. 5).

As a result of the simultaneous use of both types of illumination, images of black ring for the rollover zone was obtained. The rollover area analysis was based on measuring the width of the rings by means of the software developed in the LabView environment.

The rollover size measurement begins with detecting the center of the hole visible in the image as a white area limited by a black ring. Next, along the straight lines spreading out radially from the center of the hole, edge searching was performed (Fig. 6). Amount of the angle between these two lines was 1°. Two types of edges were detected along each line. The first one with the descending slope which is the edge of the hole in the sheet and the second with an increasing slope representing the outer edge of the rollover area (Fig. 6). For each of the two sets of coordinates corresponding to the inner and outer edges of the rollover the circles was matched. On this basis, the values of the rollover outer diameter $d_r$ and inner diameter $d_i$ were determined. Finally, the difference between these diameters was calculated, which is at the same time the width of the ring $W_r$.

4. Measurement results

The cutting process were carried out on a 2 mm aluminum sheet (Fig. 7) in which circular holes were made. A cutting plate (die) with a diameter of 16.05 mm and five punches of different diameters were used to achieve different rollover sizes.

The first five holes (1-5) cut in the plate were used to check the relationship between the clearance and width of the rollover $W_r$. Holes 6-11 cut in the second sheet were used to verify the repeatability of the measurements. The results are listed in Tab 1.
Table 1. Measurement results

<table>
<thead>
<tr>
<th>Hole number</th>
<th>Clearance</th>
<th>Hole diameter</th>
<th>( W_r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.15 mm</td>
<td>14.98 mm</td>
<td>1.01 mm</td>
</tr>
<tr>
<td>2</td>
<td>0.75 mm</td>
<td>15.33 mm</td>
<td>0.74 mm</td>
</tr>
<tr>
<td>3</td>
<td>0.40 mm</td>
<td>15.72 mm</td>
<td>0.49 mm</td>
</tr>
<tr>
<td>4</td>
<td>0.25 mm</td>
<td>15.83 mm</td>
<td>0.42 mm</td>
</tr>
<tr>
<td>5</td>
<td>0.10 mm</td>
<td>15.96 mm</td>
<td>0.35 mm</td>
</tr>
<tr>
<td>6</td>
<td>0.75 mm</td>
<td>15.31 mm</td>
<td>0.86 mm</td>
</tr>
<tr>
<td>7</td>
<td>0.75 mm</td>
<td>15.31 mm</td>
<td>0.77 mm</td>
</tr>
<tr>
<td>8</td>
<td>0.40 mm</td>
<td>15.72 mm</td>
<td>0.51 mm</td>
</tr>
<tr>
<td>9</td>
<td>0.40 mm</td>
<td>15.73 mm</td>
<td>0.50 mm</td>
</tr>
<tr>
<td>10</td>
<td>0.25 mm</td>
<td>15.84 mm</td>
<td>0.44 mm</td>
</tr>
<tr>
<td>11</td>
<td>0.25 mm</td>
<td>15.83 mm</td>
<td>0.44 mm</td>
</tr>
</tbody>
</table>

The above results shows the high repeatability of the rollover measurement and the relationship between the rollover width \( W_r \) and the applied clearance. Only for hole number 6, the measured rollover value deviates significantly from the other measurements. This is due to the fact that the sheet at the hole area, which was at the edge of the sample, was slightly bent during the punching process. Axial illumination was designed to highlight any irregularities on the surface of a flat sheet. Because the sample was bent at the hole no. 6, the image of the rollover area registered by the vision system has been disturbed leading to incorrect results.

4. Conclusions

Based on the carried out research, the following conclusions were made:
- There is a relationship between the measured width of the rollover \( W_r \) and the clearance.
- The vision measurement of the hole by means of axial and backlight illuminations enables fast and accurate evaluation of its diameter and rollover.
- Measurements carried out by means of proposed method are correct only for flat surfaces. In case when the sheet is bend, the conducted vision analysis is inaccurate (example of hole No. 6 measurement).
- Rollover width determination allows to determine the clearance in the cutting process, based on which the quality of the cutting hole surface can be estimated.

Acknowledgements

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References