On-line Measurement of Tool-edge Radius

Introduction

It is rather surprisingly to realize that there is no industrial standard to describe the sharpness of cutting tools. When a toolmaker makes cutting tools, they do it having neither standard nor measuring method of the edge roundness. That is because non-destructive on-line measurement does not exist and existing methods of measuring have no satisfactory precision.

A lot of methods have been proposed to measure the sharpness of tool-edge. However, every method is either destructive or time consuming and is not applicable to production line. The purpose of this paper is to develop a device for online, non-destructive measurement of the sharpness of the cutting tool-edge.

Principle of Method and Experimental Setup

A prototype of proposed method is shown schematically in Fig. 1. The principle of this system is to reconstruct the edge shape by its envelope lines. The reconstruction method is to detect a change in the angle of the metal strips, which forms a tangent line of the edge at a point on the edge. Laser beams are shot perpendicularly to the screen and are reflected back to the screen by the mirrors fixed above the rotation center of metal strips. One end of these strips is fixed. The tool-edge is turned around the fix center. On the screen, image of dots as like as the ones shown in Fig. 2 is expected to be seen. We will be able to know the inclinations of metal strips by reading positions of reflected points on the screen.

For reconstruction of edge shape the rotation center of metal strip is imaginary turned around instead of tool-edge center. Provided the strip centers are stable and the measurement of inclination, which is expanded by optical system, is accurate, we can obtain the line of bottom surface of metal strip, which touches the edge at a point on its surface. When the straight lines thus obtained, which compose the tangent of the edge at various points, are drawn as shown in Fig. 3, the shape of envelope curve is the shape of the edge concerned.

Experimental Results and Discussion

Experiments were carried out using model-edges, which were made in different radius to test the ability of this method. Figure 4 shows one of the cross sections of model-edges with the radius of 0.5 mm approximately. Straight lines in Fig. 5 are the envelope which forms the shape of edge. Figure 6 shows the results both of microscope readings and envelope.

In order to evaluate the accuracy of proposed method, the following measures were introduced and the result shown in Table 1 was obtained.

First, the both curves of microscope reading and envelope as like as Fig. 6 were expressed by the fourth powered linear function

\[ f = \sum_{n=1}^{4} a_n x^n. \]
The total deviation of envelope shape \( f_e \) from microscope reading \( f_m \) is defined by

\[
D_{\text{total}} = \int_{L_1}^{L_2} (f_e - f_m) \, dx,
\]

where \( L_1 \) and \( L_2 \) are the values of x-axis at the limits of edge rotation to the left and right, respectively. The average value of deviation within effective length \( L_1-L_2 \) is given by

\[
D_{\text{ave}} = \frac{D}{L_2-L_1}.
\]

Standard deviation of \( f_e \) from \( f_m \) is also obtainable by

\[
\sigma_e = \sqrt{\int_{L_1}^{L_2} (f_e - f_m)^2 \, dx \over L_2-L_1}.
\]

It is possible to express the degree of fitness of \( f_e \) by introducing a measure named normalized total error, \( \varepsilon_e \), which is defined by

\[
\varepsilon_e = \frac{E_{\text{total}}}{L_2-L_1} = \frac{1}{L_2-L_1} \int_{L_1}^{L_2} |f_e - f_m| \, dx.
\]

It is seen in Table 1 that the accuracy of this method is in the level of few micron for the cases of sharper edges. This level is certainly good enough for many industrial applications. In other words, however, this level is the maximum accuracy attainable at this stage. More accurate matching and assembly are required to each part of this device, which will results in sub-micron level of accuracy.

<table>
<thead>
<tr>
<th>Nominal radius, mm</th>
<th>Average error, ( D_{\text{ave}} ), ( \mu )m</th>
<th>Standard deviation, ( \sigma_e ), ( \mu )m</th>
<th>Effective width, ( L_1-L_2 ) mm</th>
<th>Normalized error, ( \varepsilon_e ), ( \mu )m</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.9</td>
<td>1.0</td>
<td>0.031</td>
<td>0.9</td>
</tr>
<tr>
<td>0.1</td>
<td>-0.8</td>
<td>0.7</td>
<td>0.109</td>
<td>0.4</td>
</tr>
<tr>
<td>0.5</td>
<td>-6.4</td>
<td>13.1</td>
<td>0.687</td>
<td>11.1</td>
</tr>
<tr>
<td>1.0</td>
<td>-25.0</td>
<td>32.1</td>
<td>1.208</td>
<td>25.0</td>
</tr>
</tbody>
</table>

As like as the other methods the accuracy of this method is greatly influenced by the production precision of the device parts. Although this method is not fully satisfactory in measured accuracy at present stage, yet the original purpose to measure the form of the sharp edge non-destructively in on-line system with satisfactory precision was attained. Another advantage is that this system is cheap to produce and easy to maneuver.

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