Evaluation of Machining Accuracy by Measurement of Surface Texture Pattern

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1. Introduction

Highly precision dies are increasingly required as the functions of cars, digital equipment, etc. become more and more sophisticated. Two general ways of measuring die parts are use of three-dimensional measuring machines and machine tool. However, measurements by the machine tool have efficiency and accuracy related problems, while measurements by the three-dimensional measuring machine comprise of numerous steps, resulting in lead-time problems.

In order to solve these problems, the authors developed a technique for measuring surface texture machined consistently on a machine tool and evaluating machining level differences of less than 1µm.

2. Machining of Surface Texture

1) Method of surface texture applicable for machining accuracy evaluation

Figure 1 shows the machining of a checkered surface texture in a die manufacturing shop machined at fixed pitch from two directions X and Y which intersect perpendicularly with a ball-end mill. When there is machining level difference, a gap or overlap occurs. The machining level difference can be calculated by measuring the intersection scale spacing W by geometrical calculation. In this study, the authors propose the method of machining checkered surface texture and evaluating machining level difference from the inconsistency of the patterns to verify the usefulness of the technique.

2) Verification experiments of surface texture machining accuracy evaluation system

![Fig.1 Checker pattern milling](image1)

![Fig.2 Systematic diagram of surface texturing system](image2)
The machining accuracy evaluation system consists of the main body, optical microscope incorporated in the main body, CAD/CAM/CAT system, and scan-type white light interferometer for evaluating machining accuracy. Figure 2 shows the system configuration [1]. Using this system, experiments were conducted on the following:
1) Verification of the relation between surface texture inconsistency and machining level difference by machining accuracy analysis.
2) Verification of the reliability of machining experiments for plastic.

3. Analysis of Machining Accuracy

For case 1 shown in Figure 3, continuous checkered pattern is formed when there is no machining level difference. For case 2, a gap or an overlap is generated at the intersection point when there is machining level difference.

To resolve these problems, we built three-dimensional models of both cases where a shallow cutting or deep cutting occurs as shown in Figure 4. For both cases, when machining in one direction cuts excessively, intersection scale spacing occurs, the quantity of which can be expressed with a common cross-sectional model as shown in Figure 4, and from which the relation of equation (1) can be obtained.

\[(R - H)^2 + \left(\frac{W}{2}\right)^2 = R^2 \]  

(1)

where \(R\) is the tool radius, \(W\) is the intersection scale spacing, and \(H\) is the level difference.

Consequently, level difference \(H\) can be approximated by equation (2).

\[H = R - \sqrt{R^2 - \left(\frac{W}{2}\right)^2} \]  

(2)

Figure 5 shows the relation of height difference
4. Experiments on Plastic Machining

This section describes actual machining experiments using plastic as the work material. Cases 1 and 2 in Figure 7 are the results of experiments varying the cutting depth. The width \( W \) of the intersection of a measuring point was measured, and the level difference \( H \) was computed using equation (2) and this value. Table 1 shows the results.

In order to verify the accuracy, Figure 8 and 9 shows the results of measuring with the scan-type whitelight interferometer. Table 2 shows the results of calculating the machining level difference from the actual measurement.
Table 1  Converted height difference

<table>
<thead>
<tr>
<th>Point</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W$ (µm)</td>
<td>220</td>
<td>230</td>
<td>230</td>
<td>220</td>
<td>230</td>
</tr>
<tr>
<td>$H$ (µm)</td>
<td>4.01</td>
<td>4.41</td>
<td>4.41</td>
<td>4.01</td>
<td>4.21</td>
</tr>
</tbody>
</table>

Fig.8  Measurement by scanning white light interferometer

Table 2  Converted height difference in white light interferometer

<table>
<thead>
<tr>
<th>Point</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H$ (µm)</td>
<td>4.81</td>
<td>5.07</td>
<td>4.75</td>
<td>4.50</td>
<td>4.78</td>
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</tbody>
</table>

Fig.9  Measurement by scanning white light interferometer

data. Comparison of Tables 1 and 2 confirms that this method has a measurement accuracy of 1µm or less.

5. Conclusion

In this study, the authors proposed a method of evaluating machining accuracy simply from surface texture pattern errors machined consistently. The following conclusions were reached.
1) In the analysis of machining accuracy, machining level difference up to 0.2µm or less can be identified.
2) This method is able to measure at accuracies less than 1µm in the machining of plastic workpieces.

References