DETERMINING TOOL DIAMETER FOR MACHINING OF SURFACE TEXTURE

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1. INTRODUCTION
Machining of surface texture is carried out in the manufacturing process of products such as automobiles and electronic goods to improve the touch and visual effects of product surfaces[1]. During the machining of surface texture, machining time and accuracy depend greatly on the diameter of the used ball end mill. However, there sometimes exists no appropriate tool diameter for the machining of the surfaces with pits because surface texture is composed of small asperities. In addition, the method of deciding the appropriate tool diameter can be difficult because small tool diameters need to be used. On the other hand, observations of the surface texture features show that areas around grooves at the course line, that is, at the convex part, are concave, so the surface curvature radius is small. In this study, tool diameter was calculated based on the curvature of the textured surface. The whole area of the surface was divided into machinable and non-machinable areas, and the tool diameter was gradually changed according to these areas. The tool path used in this study was assumed to be a spiral that centers on the top of a convex shape.

2. CREATION OF SURFACE TEXTURE
Figure 1 shows the procedure of creating surface textures consisting of the following steps.

(a) The designer creates the surface texture of a narrowness area where several patterns can be identified.
(b) Same shapes existing within the designed surface texture are classified according to the convex shape type[2].
(c) CL data on narrow areas is generated for each convex shape type.
(d) CL data on wide areas is generated by joining the above CL data by moving or rotating.
(e) The CL data on wide areas is mapped to the plane or geometry.
(f) The surface texture is machined by milling based on the generated CL data on wide areas.

FIGURE 1. Creation of Surface Texture
3. GENERATION OF CL DATA

As described above, CL data is created for each shape. As shown in Figure 2, a peak is defined as the highest point in its vicinity and a pit is defined as the lowest point in its vicinity. Moreover, the saddle point is defined as a point sandwiched by a ridge and valley. The course line is defined as a line connecting the points from the saddle point to the pit point with the maximum slope. And, the area enclosed by the course line is assumed to be an analytical area.

In this study, the intended tool path was assumed to be a spiral curve centering around the convex part. An Archimedes' Spiral centering on the peak was created for the X and Y planes, on conditions that the spiral distance is $D_s$ and the data distance is $d_s$. The cutting point was calculated by transcribing the data point to the convex part. Cutting points $EPo$ and $EPI$ in the analytical area were calculated respectively if the spiral curve was crossed by course lines or data boundaries as shown in the figure. The cutting point between the $EPo$-$EPI$ is taken to pass the data points of edges on the course line or data boundary[3].

4. DETERMINING METHOD OF TOOL DIAMETER

The tool diameter is calculated based on the curvature of a curved surface shape[4]. Surface curvature for deciding tool diameter is calculated using equation (1) shown below at each node composing the STL(Standard Triangulated Language) data. Figure 3 shows the method for calculating curvature.
First, taking the vertex whose curvature is to be obtained to be V, a virtual sphere S was created centering around V, and the inside of the sphere was taken to be the area influencing V. \(|A|\) is the surface area, \(e\) is an edge vector, and \(\beta(e)\) is the angle between \(n_a\) and \(n_b\) that is the normals to the surface connected by \(e\).

\[
T(v) = \frac{1}{|A|} \sum_{\text{edges}} \beta(e) \|e\| \frac{e e^T}{\|e\|^2}
\]  

In the curvature, the positive is concave surface, and the negative is the convex surface. This means that the larger the surface curvature, the smaller will the tool diameter required be. As an example, the surface curvature of the sinusoidal was calculated with three parameters; amplitude of 0.5mm, phase of 1.5 \(\pi\), and wavelength of 2.5mm, as shown in Figure 4. Figure 5 shows the distribution map of the calculated curvature. Looking at the curvature...
distribution map of the surface, it was found that curvatures near the course line are large, requiring tools with small radius in such areas. The tool diameter required can also be estimated by creating the histogram of the curvature radius as shown in Figure 6. Two tools; radius ① (2.0mm) and radius ② (0.2mm) were prepared according to the variation in the curvature radius, and as a result, the black areas shown in Figure 7 were predicted to interfere. In this way, the interfering areas of the tool with radius ① are less than that with radius ②. For both radiuses, increase/decrease of the interfering areas could be seen based on the course line. Applying the changes in the interfering areas around the course line, a tool radius can be set for each area gradually, to decrease the machined areas using a small diameter tool. This means that the tool path can be reduced by using a small tool diameter. Consequently, as shown in (a) of Figure 8, a small area of the curvature near the top should be machined with a big tool like radius①. And, as shown in (b) of Figure 8, a large area of the curvature near the course line should be machined with a small tool like radius②. This time, the amount of uncut area, that is, the cusp height, in ball end mill machining was adjusted to about 5 μm, in creating the tool path. This as a result successfully shortened the machining time, realizing efficient machining, as shown in Table 1.

5. CONCLUSION
The following conclusions were obtained by calculating the surface curvature of surface texture, examining textured surface features, deciding the tool diameter, and calculating the machining time.
(1) It was found that that course line–like concave areas with small curvature radius generated by surface curvature appears on the textured surface.
(2) Proposed a method to determine tool radius appropriate to surface features according to curvature features on the textured surface.
(3) The machining time can be shortened using tools appropriate for the surface features of surface textures.

In future studies, the machining accuracy of surface textures will be verified through actually ball end milling experiments.

<table>
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<tr>
<th>Machining method</th>
<th>Existing</th>
<th>New</th>
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<tr>
<td>Feed Rate</td>
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<td>600 μ m/sec</td>
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<td>Tool Radius</td>
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<td>R0.2mm,R2.0mm</td>
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<tr>
<td>Ds</td>
<td>50 μ m</td>
<td>50 μ m,150 μ m</td>
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<tr>
<td>Machining Time</td>
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REFERENCES