MACHINING TECHNOLOGY OF MICRO WAVED V-PATTERN USING SHAPING PROCESS

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INTRODUCTION
Recently, high-function, high-efficiency, compact and low-cost are demanded in LCD display industry. Optical films which are used in BLU are trying to enhance efficiency and low-cost through minuteness, complex and large-area. Research for micro complex pattern which used in optical film is active [1][2][3]. In generally, shaping process or planning process is applied to manufacture mold for light guide panel (LGP) and optical film which has micro pattern [4][5][6][7]. Moreover roll mold machining technology for large-area film is studying and is applied in various fields [8]. In this paper, plane micro complex pattern machining was realized. Micro waved V-pattern which is application of basic V prism pattern was tried to form. Its pattern is estimated to decrease optical interference effect such moiré [9]. It’s basic machining experiment only with using shaping system control. This paper represents that how small micro waved V-pattern can be made and analyze effect of tool feeding direction, tool relief angle and tool material.

MICRO WAVED V-PATTERN SHAPE
Figure 1 shows specification shape of micro waved V-pattern. Keeping specific height(H), this pattern consists of plural structure which has alternate amplitude of left and right along the feeding direction. Its shape is depended on pitch(P), amplitude(W) and period(T).

EXPERIMENTAL SYSTEM AND MACHINING METHOD
Figure 2 shows experimental apparatus diagram for micro waved V-pattern machining. This machine has 3-axes of driving system such as X, Y and Z axes. X and Y axes have the air static pressure bearing in driving system. Z axes is operated by servo motor. X and Y axis motion determines amplitude of left and right on machining path, position of X, Y axis. Z axis motion determines vertical position.

The each cutting force of 3-axes can be measured in real time because dynamometer is attached to the Z axis.

FIGURE 1. Shape of micro waved V-pattern and main configuration parameters

FIGURE 2. Schematic of experimental setup

Machining path is made using EdgeCAM software through arranging G02 and G03 NC code on alternation for designed period(T), amplitude(W) and pitch(P). As diamond tool follows designed path, waved shaping process is operated through system motion control. PCD and SCD tool are used. Shape angle is 90° and relief angle is 3°, 10°. Cutting depth is 5/μm and total depth is 25 through fifth processing.
TABLE 1. Experimental conditions

<table>
<thead>
<tr>
<th>Items</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>machining method</td>
<td>shaping process</td>
</tr>
<tr>
<td>workpiece</td>
<td>6:4 brass</td>
</tr>
<tr>
<td>machining tool</td>
<td>material: PCD, SCD</td>
</tr>
<tr>
<td></td>
<td>shape angle: 90°</td>
</tr>
<tr>
<td></td>
<td>relief angle: 3°, 10°</td>
</tr>
<tr>
<td>shape of pattern</td>
<td>micro waved V-pattern</td>
</tr>
<tr>
<td>pattern pitch</td>
<td>50_</td>
</tr>
<tr>
<td>cutting depth</td>
<td>5_/pass</td>
</tr>
<tr>
<td>cutting speed</td>
<td>100mm/min</td>
</tr>
</tbody>
</table>

TOOL FEEDING DIRECTION, TOOL RELIEF ANGLE AND TOOL MATERIAL EFFECT ANALYSIS

On machining micro waved V-pattern using fixed tool, the shape and size of pattern has several limitation because of the interference of the relief face of tool is occurred for the amplitude and period of pattern. The relief angle has to be considered when tools are designed because the interference is differently occurred by amount of relief angle. Tool motion of micro waved V-pattern can be considered to linear shaping path with continuous changed tangent slope as Figure 3. On the machining path, tangent slope has biggest angle for Y-axis of feeding direction in inflection point and its point is maximum contact angle.

The effect of interference between tool relief face and workpiece can be estimated by feeding the tool in cutting path obtained by the maximum contact angle occurred for the change of amplitude and period.

Table 2 shows maximum contact angles as main configuration parameter of micro waved V-pattern. Maximum contact angle increases for decreasing of pattern period on fixed amplitude. Linear shaping experiment was carried out for obtained maximum contact angle as Fig 3.

TABLE 2. Maximum cutting angle of each micro waved V-pattern

<table>
<thead>
<tr>
<th>Contents</th>
<th>Amplitude (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50_</td>
</tr>
<tr>
<td>Period (T)</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>500_</td>
</tr>
<tr>
<td></td>
<td>300_</td>
</tr>
</tbody>
</table>

FIGURE 3. Maximum cutting angle of micro waved V-pattern

Figure 4 shows result surface of linear shaping experimental. It is more difficult to form pattern as maximum contact angle increases because interference of tool relief face breaks down machined pattern. And the interference of relief angle 3° is bigger than the one of relief angle 10°.

On machining micro waved V-pattern, it is necessary to design proper pattern shape and to consider tool relief angle for minimizing interference effect of tool relief face.

FIGURE 4. Comparison of machined surface for maximum cutting angles

Figure 5 shows the result of machined surface of micro waved V-pattern using PCD tool with relief angle 3° on pattern shape designed as table 2. Formation of pattern is bad as maximum contact angle increases more and more due to inference of tool relief face on machining micro waved V-pattern in Figure 5(a), 5(b) and 5(c).

Additional experiment with maximum contact angle 11° for each period carried out.

Although the results of machined surface can not be quantitatively compared, they are nearly similar as Figure 5(d), 5(e) and 5(f).

Figure 6 shows cutting force diagram which was measured on fifth pass.

Sampling time which is horizontal axis is equal.
Cutting force of X axis and Z axis are much bigger than major cutting force of Y axis. And each of cutting force has periodicity because tool motion operates by periods. They alternate value within specified range and show sine waved shape. At inflection point, inference of tool relief face was greatly occurred. Although maximum contact angle increases, cutting force decreases because of decreasing of cutting section area which was due to inference of tool relief face.

In this experiment, micro waved V-pattern which has 300° of period and 15° of amplitude was realized.

Micro waved V-pattern experimental using PCD and SCD with relief angle 10° was carried out on same condition.

Figure 7 shows different of machined surface according to the kind of tool type. The result of tool relief angle 10° is good comparing with Figure 5 machined result of tool relief angle 3°. The machined surface by PCD tool is rough and have scratch and burrs but the surface by SCD tool is clear and does not have any scratch and burr.

Figure 8 shows the shape of cutting chip formed in micro waved V-pattern mold that machined by using SCD tool with relief angle 10°. On the whole flow type chip was formed but the chip was regularly damaged on the right and left of cutting chip in same pitch. Interference of tool relief face was most greatly occurred at the near inflection point.
Cutting force measured by SCD tool is smaller than the one of PCD tool on same condition.

(a) T1000_, W50_  (b) T500_, W25_  (c) T300_, W15_
by PCD tool

(d) T1000_, W50_  (e) T500_, W25_  (f) T300_, W15_
by SCD tool

FIGURE 9. Comparison of cutting force according to tool material with relief angle 10°

CONCLUSIONS
1. Basic machining experimental of micro waved V-pattern was carried out using system motion control on high precision shaping process and micro machining technology of micro waved V-pattern with period 300_ and amplitude 15_ was founded.
2. On machining micro waved V-pattern using fixed tool, it is necessary to design range of amplitude within tool relief angle for minimizing interference effect of tool relief face.
3. Maximum interference of tool relief face occurs near inflection point and deviation of machined surface is greatest in this point
4. It's necessary to decrease interference effect of tool relief face for machining wide amplitude micro waved V-pattern.
5. Machined surface and patterned shape of SCD tool is better than it of PCD tool on same machining condition

REFERENCES