Development of New Honing Machine with Electrolytic Interval Dressing Capability
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Abstract

With new materials such as ceramics increasingly applied to precision machine parts, the precision requirement of precision machining grows stricter year by year. In order to utilize these difficult-to-machine materials for the widely used cylindrical machine parts, it is crucial to attain high machining precision, high machining level, and high machining efficiency at the same time. But this proves extremely difficult in mass production. To solve these problems, the authors developed a new honing machine, which realizes highly efficient and excellent mirror surface grinding using metal-bond diamond wheels, applying electrolytic interval dressing functions to stabilize its grinding accuracy. The investigations carried out confirmed its application merits.

Key words: honing machine, electrolytic interval dressing, metal-bond diamond grinding wheel, ceramics, internal mirror surface of small diameter.

1. Introduction

The advantages in using ceramics for precision machine parts include wear-resistance, thermal-resistance, chemical-resistance, etc. High dimensional accuracy, high profile accuracy, and high surface finishing must be attained in the machining of these products. Most of precision parts made of those tough materials require good fitness and surface quality as machine components, and therefore, a revolutionary honing machine for the next generation should be established to finish the cylindrical internal surfaces of relatively small small diameters more effectively. In this study, a new honing machine realizing honing processes with a new philosophy using ELID capabilities was developed and its application was attempted.

2. Development of ELID honing machine
2-1 Electrolytic interval dressing method

To apply electrolytic in-process dressing (ELID) /1/ to the machining of small internal diameters which are difficult to fit with electrodes, and electrolytic interval dressing (ELID II) grinding method described in Figure (1) /2/ which performs intermittent dressing was developed. This method has helped realize the internal mirror-surface grinding of very hard materials.

2-2 ELID honing grinding procedure

Figure 2 shows the grinding procedure in which ELID II -grinding was applied to the honing machine /3/. After initial truing of the metal bond wheel for forming to be round in the cross section by EDM (R-forming), intermittent electrolytic dressing was performed (ELID honing). Figure 3 also shows an application of this new honing principle which aims at improving the finishing efficiency by using a negative electrode fixed out of the workpiece end-face by reducing the positioning time of the electrode as in the grinding procedure shown in Fig.2.

![Fig.1 Principle of ELID II -grinding](image1)

![Fig.2 Principle of ELID honing method](image2)

![Fig.3 Application of ELID honing](image3)

3. ELID honing experiment system

The experiment equipment for the ELID honing is shown in Table 1.

Table 1 Specifications of ELID honing experimental system
3-1 Honing machine

The base machine of the developed ELID honing machine is the CMH-200-N-S (made by Nissin Manufacturing) whose specifications are summarized in Table 2.

<table>
<thead>
<tr>
<th>Grinding machine</th>
<th>Vertical honing machine: CMH-200-N-S (Nissin Manufacturing), ELID device: electrode drive unit with EDM functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding wheel</td>
<td>Steel-bond (FX3) diamond wheel, Mesh: #325, #4000, Concentration: 100 (L30xW3mm: grindstone) [Sintobrator]</td>
</tr>
<tr>
<td>Power supply</td>
<td>DC-pulse generator: EDD-04S [Sintobrator]</td>
</tr>
<tr>
<td>Workpiece</td>
<td>Silicon carbide (SiC), Zirconium oxide (ZrO₂), [Nihon Cerate], Tungsten carbide (WC with Co cemented carbide) [Fujii Die] (the material properties shown in Table 3)</td>
</tr>
<tr>
<td>Fluid</td>
<td>AFG-M + tap water (2% dilution of water) [Norton Company]</td>
</tr>
</tbody>
</table>

This unit was incorporated with the ELID power supply, automatic electrode positioning device, and an exclusive program developed for it. Figure 4 shows the external view.

3-2 Honing wheels

Metal-bond diamond wheels composed of four each rectangular grindstone (honing stone) of #325 and #4000 with 100 diamond abrasive concentration were used as the honing wheel.

3-3 Fluid and workpieces

The grinding fluid used was AFG-M diluted 50 times with tap water. This is a conventional chemical-solution-type fluid. Workpieces of typical ceramic materials of which properties are shown in Table 3 were ground in the experiments. The size of the workpiece was:
External diameter: ↓ 30mm
Internal diameter: ↓ 17.8mm
Length: L 30mm

Table 3 Properties of typical ceramic materials used in the experiments

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness Hv kg/mm²</th>
<th>Bending strength kg/mm²</th>
<th>Fracture toughness MN/m² ²</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>2400</td>
<td>60</td>
<td>3</td>
<td>0.16</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>1200</td>
<td>120</td>
<td>10</td>
<td>0.31</td>
</tr>
<tr>
<td>WC</td>
<td>1650</td>
<td>220</td>
<td>12</td>
<td>0.21</td>
</tr>
</tbody>
</table>

4. ELID honing experiments

4-1 Experiment procedure

After truing the wheels by EDM, ELID honing was performed. The #325 wheel was used for rough grinding while the #4000 wheel was used for fine grinding. The reliability of the honing operations was evaluated according to the stability of the spindle load. The surface roughness and roundness was evaluated by using a surface measuring instrument with a diamond stylus of 5 ∞m radius, and roundness tester (Taly Rond 210: Rank Taylor Hobson), respectively.

4-2 Experiment results and discussions

1) ELID honing conditions

Table 4 shows the ELID honing conditions for silicon carbide. Conditions were selected placing importance on reliability than on performance. The cemented carbide was given a higher wheel speed than the other wheels.

Table 4 ELID honing conditions

<table>
<thead>
<tr>
<th>Honing conditions:</th>
<th>#325</th>
<th>#4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel mesh size</td>
<td>315</td>
<td>315</td>
</tr>
<tr>
<td>Wheel revolution rpm</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Feed-rate m/min</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Skip-time pass</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Expansion µm</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Total expansion</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Clean-up time s</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Dwelling time s</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

ELID conditions:
Eo140V, Ip3A,T,τ,μs,τ,μs,1.7 μs(commonly used)

2) Effects of wheel grit size

Figure 5 shows the ELID honing roughness patterns of each workpiece by the #325 and #4000 wheels. A Rmax of 0.2 to 0.3 ∞m was obtained with the #325 wheel, and Rmax of 0.03 to 0.05 ∞m with the #4000 wheel. A ten-fold improvement was seen when the grit size was decreased.
3) Effects of workpiece

Because silicon carbide has lower fracture toughness than cemented carbide, poor surface roughness was obtained with all grit sizes. The values obtained for cemented carbide were half those of silicon carbide. Surface roughness less than Rmax 30nm was realized with the #4000 wheel.

4) Effects of ELID conditions

The ELID conditions of the #4000 wheel especially affect the reliability of machining. Of these, the number of dresses and average current are particularly important. 10/20 was required for the number of grinding /dresses and about 0.5A for the average current.

5) Honing roundness

Figure 6 shows the roundness measured with the cemented carbide ground by ELID honing using the #4000 wheel. Good roundness of 0.15 ∝m was obtained together with a surface roughness of Rmax 23nm.

6) Future tasks and prospects

Based on these results, applications to other difficult-to-machine materials will be attempted. Reduction of the number of dresses, application of #1000 to #2000 grit size, and the optimum wheel bond material and grinding fluid will be undertaken one by one. Figure 7 shows the samples produced by the developed ELID honing machine.
5. Conclusions

In this study, a new honing machine with ELID capabilities was developed, realizing the ultra-precision mirror surface grinding for internal surfaces with small diameter. This new machining process composed of honing and electrolytic interval dressing enabled highly efficient and stable honing for typical ceramic materials such as SiC, ZrO2, and WC. Smooth surface finish and high surface accuracy for small internal diameter, were successfully achieved through the trial optimization of the process.

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References