Study on Magnetic Field Assisted Machining Process Using Magnetic Machining Jig (Application to Internal Finishing of Thick Stainless Steel Tube)

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Introduction

Conventional magnetic abrasives have been used in magnetic field-assisted machining process for internal precise finishing. However, it is difficult to finish internal surfaces of thick tubes (more than about 5 mm in thickness) by using the magnetic abrasives, because magnetic force (finishing force) weakens when the thickness of tube becomes thick. A new efficient process for internal finishing of thick tube (10–20 mm in thickness) using magnetic machining jig was proposed. Moreover, this process was developed using magnetic particles and using abrasive slurry.

In this method, magnetic particles were placed on the surface of magnet attached to magnetic machining jig and were strongly magnetically attracted. While the magnetic machining jig follows the rotation of pole with the magnetic particles, the relative motion between work surface and magnetic particles is generated, the abrasive behavior is performed indirectly from magnetic particles to abrasive grains, and the precise finishing was achieved. In the present study, this method has succeeded in a model experiment in which a brass plate (10 mm in thickness) was used as a workpiece [1][2].

In this paper, the principle of this method for internal precise finishing of thick tube using magnetic machining jig is described. The magnetic machining jig and the experimental setup applied to the internal finishing of thick tube were manufactured. Finally, an experiment was carried out and the results of the experiment showed that precise internal finishing of thick tube could be achieved by using this process.

Comparison using magnetic abrasives with using magnetic machining jig

Figure 1 shows the schematics of magnetic field assisted machining process for internal precise finishing using magnetic abrasives and using magnetic machining jig. As shown in Fig. 1(a), the advantage of using magnetic abrasives is that flexible processing behavior can be obtained along the surface of tube. Therefore, the shape of workpiece was kept together with the surface accuracy of the workpiece can be improved. However, the magnetic force (finishing force) weakens when the thickness of tube becomes thick. As a result, the processing will fall in impossibility when the thickness of tube is more than 10 mm. To overcome this problem, a new magnetic field-assisted machining process using magnetic machining jig shown in Fig. 1(b) was proposed. As shown in Fig. 1(b), in case of an N-S type of machining jig was used, a magnetic closed circuit can be formed, the magnetic resistance in a magnetic circuit is decreased and the magnetic force is increased. Therefore, internal finishing of thick tube can be achieved.

Fig.1 Comparison using magnetic abrasives with using magnetic machining jig

Processing principle

Figure 1(b) shows a schematic of the internal finishing process using a magnetic machining jig by the use of a pole rotation system [3][4]. The magnetic machining jig placed in the tube is magnetically attracted by the poles placed outside the tube, pushing the inner surface of the tube by the generation of magnetic force. When the poles are rotated around the tube, the machining jig follow rotate along the inner surface of the tube by magnetic force (finishing force) together with the rotating poles, resulting in occurrence of relative movement between the magnetic machining jig and the tube.

If the rotating poles are driven in the direction of the tube axis, the magnetic machining jig is also driven by the magnetic force in the direction of the tube axis while rotating along the inner surface of the tube. As a result, finishing of the entire inner surface of the tube is achieved. An N-S type of magnetic machining jig was used in this experiment as shown in Fig. 1(b). When the abrasive paper was wrapped on the magnetic machining jig, the finishing could be achieved easily like bonded-abrasive machining.

Moreover, a new process was proposed using magnetic machining jig, and using magnetic particles and abrasive slurry. In this method, magnetic particles were placed on the surface of magnet attached to magnetic machining jig and were strongly magnetically attracted. While the magnetic machining jig follows the rotation of pole with the magnetic particles, the relative motion against the inner surface of tube is generated, and the abrasive behavior is performed indirectly from magnetic particles to abrasive grains, the precise finishing is achieved. Because the problem of...
Table 1 Experimental conditions

<table>
<thead>
<tr>
<th>Workpiece</th>
<th>SUS304 stainless steel tube Ø89.1x0.79.1x&lt;500mm</th>
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</thead>
<tbody>
<tr>
<td>Initial surface roughness:</td>
<td>31.4μmRa, (4.5μmRy)</td>
</tr>
<tr>
<td>Revolution:</td>
<td>34min</td>
</tr>
</tbody>
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<table>
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<tr>
<th>Magnetic machining jig</th>
<th>Magnet: Nd-Fe-B rare earth permanent magnet Yoke: SS400 steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pole</td>
<td>Magnet: Ferrite magnet (50x35x26mm) Yoke: SS400 steel</td>
</tr>
<tr>
<td>Pole revolution:</td>
<td>415min</td>
</tr>
<tr>
<td>Pole feeding speed:</td>
<td>1.2m/min</td>
</tr>
</tbody>
</table>

1st-step processing | Abrasive paper: #100 WA resinoid-bonded abrasive cloth, Finishing time: 70min; #1000 WA slurry: 5wt% |

2nd-step processing | Magnetic particle: Iron particles (510μm in mean dia.), Finishing time: 30min; Diamond slurry: 7.5wt% (12μm in mean dia., 2.4μm) |

Clearance | 7 mm |

abrasive paper life can be solved and the size of magnetic particle and abrasive grain can be selected freely by this technique, high-precision process could be achieved.

Experimental setup and conditions

Figure 2 shows an external view of the experimental setup for the internal finishing process using a magnetic machining jig. A finishing unit, consisting of magnet poles attached inside a yoke, was set up on the carriage of a lathe, and a stainless steel tube as a workpiece was fixed between the chuck and the tail stock center of the lathe. Ferrite magnets were used as poles for the safety of processing environment and the poles are big (50x35x26mm) for the increase of the finishing zone in this experiment, but sufficient magnetic force (finishing force) can be obtained because of using the magnetic machining jig. The poles were set symmetrically toward the tube center in an N-S-S-N pole arrangement. Even though the distance between the pole tip and magnetic machining jig is bigger, the higher magnetic force can be achieved. In order to confirm that a tube of 10 mm in thickness can be finished, a tube of 5 mm in thickness was used as a workpiece, and the distance between the pole tip and the tube was set at 7 mm in this experiment. It is thought that the same result can be obtained when a tube of 10 mm in thickness was used, and the distance was set at 2 mm. The finishing unit can be driven in the direction of the tube axis with the carriage of lathe as the pole rotating.

Fig.3 Composition and photograph of the magnetic machining jig

Figure 3 shows composition and photograph of magnetic machining jig. The experimental conditions are shown in Table 1. A two-step process was performed in this experiment. As shown in Fig.3, an abrasive cloth and abrasive slurry were used in the first-step processing, and magnetic particles and abrasive slurry were used in the second-step processing.

Experimental results

Figure 4 shows the photographs of the inner surface of the tube before and after finishing. The results show that the initial surface roughness of 4.5 μmRa (31.4 μmRy) was improved to 0.4 μmRa (4 μmRy) by the first-step processing and that the surface roughness was improved rapidly from 0.4 μmRa (4 μmRy) to 0.1 μmRa (1.1 μmRy) by the second-step processing when an SUS304 stainless steel tube of 10 mm in thickness was used and the finishing zone was set at 150 mm. The results showed that this process enables precise internal finishing of a thick tube.

Fig.4 Photographs and surface roughness of the inner surface of the tube before and after finishing

Conclusions

A new efficient internal finishing process for a thick tube was developed using a magnetic machining jig. Finishing experiments were carried out, and the results showed that this process enables precise internal finishing of a thick tube (10 mm in thickness).

References