Study on Plane Magnetic Abrasive Finishing Process
- Experimental and Theoretical Analysis on Polishing Trajectory-

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The purpose of this study is to find out an effective method to elevate the surface precision and homogeneity by improving the polishing trajectory of magnetic brush. The moment of magnetic brush is a key factor affecting on finishing results, while movement is relatively simple in conventional process. In this paper, complex polishing trajectory of magnetic brush has been modified and studied by use of newly designed experiment device. In comparison with conventional process, variation regularity about surface roughness and the material removal are been studied. According to experimental results and theoretical analysis, a lot of characteristics of trajectory have been summarized. The results show that studies on trajectory of magnetic brush are useful and the experimental researches are consistent with theoretical analysis. In addition, the precision of plane magnetic abrasive finishing can be elevated in terms of the reasonable planning for polishing trajectory of magnetic brush.

1 Introduction
As a ultra-precision machining method, the plane magnetic abrasive finishing process has many profits: high quality, good flexibility and strong adaptability etc. A lot of traces can be removed and surface roughness can be improved by use of this process. It has irreplaceable advantages comparing with the others machining process. While as a plane finishing technology, not only surface roughness, but also micro-shape and plane homogeneity should be inspected to further elevate the surface precision. The moment of magnetic brush has great influence on the finishing results, so the main study purpose of this paper is to improve the trajectory of magnetic brush.

2 The difference between conventional process and improved process
The moment trajectory of magnetic brush is shown in Fig.1(a) in the conventional plane magnetic abrasive finishing process. The motions are composed of revolution of magnetic brush and linear moment of workpiece. The finishing depth and surface roughness are different in the whole finishing district. In this paper a new project is proposed, the revolution and rotation of magnetic brush and the linear moment of workpiece are realized by new designed device. The improved plane magnetic abrasive process can elevate the surface precision and homogeneity. The trajectory of magnetic brush in improved process is shown in Fig.1(b).

(a)Conventional process  (b) Improved process

![Fig.1 Trajectory of magnetic brush](image)

The improved trajectory analysis of magnetic brush is as shown in Fig.2. A random point Q in magnetic brush move to Q’ after t seconds, then the coordination formula of Q is shown in Formula (1).

\[
\begin{align*}
\dot{x}(t) &= r_1 \cos(\omega_1 t + \alpha) + r_2 \cos(\omega_2 t - \alpha) + \alpha \\
\dot{y}(t) &= r_1 \sin(\omega_1 t + \alpha) + r_2 \sin(\omega_2 t - \alpha) + \alpha + v t
\end{align*}
\]

Where brush rotation radius is \( r_1 \) mm; brush rotation angular velocity is \( \omega_1 \), rad/s; revolution radius of Q is \( r_2 \) mm; revolution angular velocity is \( \omega_2 \), rad/s; the speed of linear slider is \( v \), mm/s; the original angle of Q is \( \alpha \), rad.

3 Experimental device and conditions
Fig.3 shows device structure drawing of plane magnetic abrasive finishing. Magnetic shaft is driven by a flexible shaft connected with motor; moment and rotation of magnetic brush in XY coordination plane can be realized by stage; the linear moment of workpiece base is realized by linear slider. The speed of stage and linear slider can be set by computer according to experiment requirements. The workpiece is fixed to base by vacuum absorption. Vacuum degree can be set by vacuum gauge that can adjust the pressure by regulate the operation of air pump. Therefore, the closed loop control of vacuum degree has been realized. The workpiece deformation is largest in central position of SUS304 steel plate that analysis results are calculated by finite element method software. The deformation is approximately 9.0×10-3mm when the vacuum degree approach to -88kPa, comparing with the clearance between the workpiece and magnetic brush is smaller as times as 1/500. So it is feasible to fix workpiece by use of vacuum absorption.

![Fig.2 Trajectory analysis](image)

Table 1 Experimental conditions

<table>
<thead>
<tr>
<th>Workpiece</th>
<th>SUS304 stainless steel plate, 100×100×1mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed type and magnetic abrasive</td>
<td>Iron particles (mean dia: 30 µm): 2.8 mg  KMX powder (mean dia: 5 µm): 0.7 mg</td>
</tr>
<tr>
<td>Magnet</td>
<td>Permanent magnet Φ10×10mm</td>
</tr>
<tr>
<td>Work-Pole tip clearance</td>
<td>0.5mm</td>
</tr>
<tr>
<td>Pole revolution</td>
<td>438 min</td>
</tr>
<tr>
<td>Stage speed and pole rotation trajectory</td>
<td>Conventional process: 0mm/s, 0mm  Improved process: 6mm/s, Φ10mm</td>
</tr>
<tr>
<td>Linear slider speed v and feed length L</td>
<td>v=10mm/min, L=30mm (Reciprocating)</td>
</tr>
</tbody>
</table>
4 Experimental results and theoretical analysis

The Φ10mm diameter magnet is used in two processes. But finishing width of single pass is 10mm in conventional process and 20mm in improved process, in order to compare the results difference, the finishing time in improved process is as two times long as in conventional process. The surface roughness and cross-sectional shape are measured in conventional process and improved process as shown in Fig.4. The measurement length of surface roughness is 4mm in positions A, B and C. The cross-sectional shapes are measured in P-P position.

The change laws of surface roughness(Rz) with time are separately shown in Fig.5. Fig.5(a) shows the decreasing speed of roughness in positions A and C are faster than in position B in conventional finishing process. The roughness values are obvious different in three positions. The results are completely different in improved trajectory of magnetic brush process as shown in Fig.5(b). The decreasing speed of roughness in position B is the fastest. Although they are also different in three measure position, but all the roughness values are close to each other.

The chart indicates that the more material removals are in these positions, which is consistent with the experimental results. By the same mode, there are more material removals in position B in improved process and the results are also consistent with the experimental results. The sizes of relative homogeneity district Z1 and Z2 are different in two processes. It is obvious that higher percentage of homogeneity in finishing district is higher in improved finishing process.

By comparing with the two processes, it can be discovered that the surface homogeneity has been elevated by use of improved finishing trajectory of magnetic brush in the same experimental conditions. The highest finishing depth is 1/3 by contrast with conventional process and the percentage of homogeneity district has been elevated in improved finishing process. So the method using trajectory of magnetic brush is planned in improved finishing process. The surface micro-shape and surface homogeneity are elevated; finishing efficiency is also raised by using of improved finishing process. The surface micro-shape and surface homogeneity are elevated; finishing efficiency is also raised by using of improved finishing process. The theoretical analysis is consistent with the experimental results. According to actual workpiece structure characters and surface precision requirement, finishing efficiency and surface precision can be elevated in terms of the reasonable planning for polishing trajectory of magnetic brush.

5 Conclusions

This paper compared the conventional finishing process with improved finishing process. The trajectory of magnet brush is planned in improved finishing process. The surface micro-shape and surface homogeneity are elevated; finishing efficiency is also raised by using of improved finishing process. The theoretical analysis is consistent with the experimental results. According to actual workpiece structure characters and surface precision requirement, finishing efficiency and surface precision can be elevated in terms of the reasonable planning for polishing trajectory of magnetic brush.

Reference

1) Y.You, T.Shinmura, F.Wang: Study on a magnetic deburring method by the application of the plane magnetic abrasive machining process, Advanced materials research Vol.76-78(2009), P.276-281