STUDY ON THE ROUND-OFF TRUING METHOD
USING CIRCULAR MOTION
- TRUING OF A SUPERABRASIVE WHEEL WITH A HOMOGENEOUS TRUING WHEEL -

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Abstract
The round-off truing method of a grinding wheel for precision form grinding, where the circular motion of a CNC grinding machine and an abrasive stick are utilized, was previously proposed by the authors. In a former study, the compensation method of mal-distribution of wear ratio, \( \alpha \), for an abrasive stick was proposed and the use of this method resulted in the improvement of truing accuracy. This method, however, can not be applied to a brake truer. In this study the authors have tried to produce a homogeneous truing wheel for a brake truer, utilizing a hydraulic pressure process, and the developed wheel was applied to the round-off-truing experiment for a bronze bonded superabrasive wheel. The superabrasive wheel was trued in target accuracy in about 20 minutes when setting angle of the brake truer, \( \theta_z \), was at 10 degrees.

Key words: grinding wheel, round-off truing, superabrasive wheel, homogeneous truing wheel, truing accuracy, setting angle, wear ratio

1. Introduction
An envelope grinding method using a spherical wheel or a straight wheel with round-off (toroidal shape) is usually employed to fabricate non-axisymmetric aspherical lenses and their dies. In this case, the form error of the grinding wheel directly affects the form accuracy of the generated shape.

The authors previously proposed a simple round-off-truing method utilizing the circular motion of a CNC grinding machine as shown in Figure 1 [1]. In this method, a brake truer (or an abrasive stick) was set on the machine table, and the grinding wheel was moved around the truing wheel along the circular path. In a former study [2], truing experiments for a conventional grinding wheel were performed to realize the effects of geometrical and motional error factors on the truing accuracy. As a result, the distribution of wear ratio of truing wheel, \( \alpha \), was realized to have a strong effect on the truing accuracy. The compensation method of the mal-distribution of \( \alpha \) for an abrasive stick was then proposed and the use of this method resulted in the improvement in truing accuracy. This method, however, can not be applied to a truing wheel for a brake truer even though the truer is far more efficient than the abrasive stick.

In this study, the authors have tried to produce a homogeneous truing wheel for the brake truer, utilizing a hydraulic pressure process, and the developed wheel has been applied to the round-off-truing experiment of a bronze bonded superabrasive wheel.

2. Method and Conditions of the Experiment
In the truing experiment, a high-precision CNC surface grinding machine, Kuroda SPG-25, was used. Before the experiment the profile of the grinding wheel surface was transferred to a graphite plate. The edge of the plate was traced by a ultra-accurate 3-D profilometer, Panasonic UA3P-4, to evaluate the radius of the best-fit circle, \( R_{ft} \). In the truing experiment, \( R_{ft} \) was set to the objective radius of grinding wheel, \( R_g \). Circular motion radius, \( G \), is given by the equation:

\[
G = R_g \left( \frac{T_s}{T_g} + 1 \right)
\]

where \( T_s \) and \( T_g \) are thicknesses of the abrasive stick and the grinding wheel respectively [3].

In the experiment, a brake truer was set on the machine table and the grinding wheel was down-fed and moved around the truer along the circular pass. Following the first pass, the wheel was down-fed again and circularly moved in the reverse direction. After a certain number of truing passes, the profile of the wheel surface was transferred to a graphite plate, and \( R_{ft} \); form error, \( E_R \); and form error from the circle of the minimum square, \( E_{Rft} \).
were evaluated by using the UA3P-4. Experimental conditions are shown in Table 1.

3. Results and Discussions

The production process of a conventional grinding wheel is the molding, through the press forming process of the mixed wheel materials, and the firing. Because of friction between the molding die and the wheel materials the produced wheel usually shows a mal-distribution in structure and hardness in the direction of the wheel width. In order to obtain the homogeneous wheel, the hydraulic pressure process has been applied for the molding.

3.1 Distribution of $\alpha$ of the newly developed truing wheel

Homogeneity of the newly developed truing wheel has been evaluated through infeed grinding tests as shown in Figure 2(a). In the experiment, the free end of the truer spindle was supported by the tailstock to avoid inclination of the spindle due to a vertical truing force.

When total depth of cut, $T$, is at 4mm, form deviation of the trued grinding wheel becomes more than 200$\mu$m. However, this result does not show non-homogeneity of the developed truing wheel because the form deviation of the grinding wheel is also affected by the non-homogeneity of the grinding wheel itself. The truing wheel was then turned over and the infeed grinding was performed again. As shown in Figure 2(b), the shape of the form deviation was not changed before or after the turning over. This result shows that the distribution of $\alpha$ of the developed truing wheel is homogeneous.

A similar experiment was performed using a traditional truing wheel which is available on the market. As shown in Figure 3(a), form deviation was reached at about 700$\mu$m and when the truing wheel was turned over the shape of the form deviation, shown in Fig.3(b), became quite different from that in Fig.3(a). This result implies that the structure and hardness of both wheels are not homogeneous.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Conditions for the truing experiment</th>
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<tbody>
<tr>
<td>Grinding wheel</td>
<td>Conventional wheel: GC120H ($D_g$180 x $T_g$25.4mm)</td>
</tr>
<tr>
<td></td>
<td>Superabrasive wheel: SD1500N75MB, SD2000N75MB ($D_g$150 x $T_g$25mm, Bronze bond)</td>
</tr>
<tr>
<td>Truing wheel</td>
<td>Newly developed wheel, Traditional wheel: C150K ($D_s$100 x $T_s$25.4mm)</td>
</tr>
<tr>
<td>Wheel speed</td>
<td>$V$ 1500min$^{-1}$</td>
</tr>
<tr>
<td>Cross feed speed</td>
<td>$v/f$ 300mm/min</td>
</tr>
<tr>
<td>Down feed</td>
<td>$t$ 5$\mu$m</td>
</tr>
<tr>
<td>Grinding fluid</td>
<td>W-2 type 3, 50 times dilution</td>
</tr>
</tbody>
</table>

![Figure 2](image_url)  
(a) Before turning over  
(b) After turning over  
Fig.2 Form deviation of the grinding wheel when the newly developed truing wheel is used

![Figure 3](image_url)  
(a) Before turning over  
(b) After turning over  
Fig.3 Form deviation of the grinding wheel when a traditional truing wheel is used
3.2 Round-off truing of a superabrasive wheel

Figure 4 shows the transition of $R_{ft}$ with the number of truing passes, $n$, when a bronze bonded superabrasive wheel (SD1500N75MB) was trued with the homogeneous truing wheel or a traditional truing wheel. In these cases, $R_{ft}$ becomes less than the objective radius, $R_{g}$. Figure 5 shows the transition of $E_{r}$ and $E_{ft}$ with $n$. In the range of the experiment, the form error is not small and it gradually increases with $n$.

Figure 6 shows an example of measured form deviation of the trued wheel surface. In this case, large corner dullness can be observed at both ends of the trued wheel surface. This phenomenon occurred because both ends of the wheel surface always engaged against the truing wheel with full depth-of-cut [1]. Due to the corner dullness, $R_{ft}$ was estimated at less than the objective radius as shown in Fig.4. Both ends of the grinding wheel, however, are not used in free form grinding. Thus, we had to evaluate the radius and the form deviation of the wheel surface of actual use. Hereafter, we estimate the radius of the best-fit circle without considering the ranges of $T_{g}/8$ from both ends of the wheel surface, $R_{ftC}$; form error in the same area, $E_{RC}$; and form error from the circle of the minimum square in the same area, $E_{RftC}$.

Figure 7 shows the transition of $R_{ftC}$ with $n$. In the case of the developed truing wheel, $R_{ftC}$ almost settled to the objective radius, where $R_{g}$=75mm. On the other hand, in the case of a traditional truing wheel, $R_{ftC}$ did not settle to the objective radius because the distribution of $\alpha$ was not even.

Figure 8 shows the transition of $E_{RC}$ and $E_{RftC}$. $E_{RC}$ and $E_{RftC}$ for the developed truing wheel are about 2$\mu$m in 50-200 truing passes. Even when the developed truing wheel was used, $E_{RftC}$ showed a slight increase with $n$ because the wheel was not completely homogeneous. Figure 9 shows the form deviation curve of the trued wheel surface when $E_{RftC}$ attained the minimum value.

3.3 Effect of the setting angle of the brake truer

In the latest study [2], the authors investigated the effects of setting angle of brake truer, $\theta_z$, using a
traditional truing wheel and experimentally confirmed that the inclination of the truing wheel resulted in improvement in form accuracy of a trued wheel when $\theta_z$ was set at 10-20 degrees. Figure 10 shows the form deviation of the superabrasive wheel, SD2000N75MB, which was round-off trued with the homogeneous truing wheel when $\theta_z=10$ degrees.

Since the circular motion error of the grinding machine is about $\pm0.7\mu m$ [4] and the range of the circular motion during the round-off truing is only a part of the full circular motion, the target accuracy of the proposed round-off-truing method was set at $\pm0.5\mu m$. From Fig.10, the superabrasive wheel has been trued around the target accuracy in about 15 minutes ($n=80$ passes) by using the homogeneous truing wheel and under the condition of $\theta_z=10$ degrees. In the present truing condition, the number of truing passes, $n$, must not exceed 150 passes because truing accuracy gradually deteriorates when $n$ exceeds about 200 passes.

4. Conclusions

In this paper, the authors tried to produce a homogeneous truing wheel for a brake truer utilizing the hydraulic pressure process and the developed wheel was applied to the round-off-truing experiment of a bronze bonded superabrasive wheel. The main results obtained are as follows:

(1) The distribution of wear ratio, $\alpha$, of the newly developed truing wheel was experimentally investigated and its homogeneity was confirmed.

(2) The use of the homogeneous truing wheel resulted in a significant improvement in truing accuracy.

(3) A superabrasive grinding wheel can be trued around the target accuracy as $\pm0.5\mu m$ in about 20 minutes, when setting angle of the brake truer, $\theta_z$, is at 10 degrees.

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References


