STUDY OF ELECTRICAL DISCHARGE MACHINING FOR TRUING OF DIAMOND GRINDING WHEEL

Apiwat Muttamara  
Faculty of Engineering, Thammasat University  
Pathumthani, Thailand

Choosak Phumueang  
Faculty of Engineering, Thammasat University  
Pathumthani, Thailand

ABSTRACT

This study deals with fundamental investigations are presented regarding the possibility of EDM for truing of metal bonded diamond grinding wheels. These wheels are often used for precision grinding operations of hard glass materials like ceramics. They are characterized by high profile constancies and wear resistances. Due to the electrical conductivity of the bond material, EDM offers an efficient and powerful alternative to conventional trueing and dressing. Achievable grit protrusion and possible thermal damage to smallest diamond grits are theoretically and experimentally examined. Additionally, machining strategies for high profile accuracy are presented.

KEYWORDS— Electrical Discharge Machining (EDM), Metal Bond Diamond Grinding Wheel, Copper Tungsten, Electrical Pulse Shape, Diamond Grit.

I. INTRODUCTION

Nowadays, diamond grinding wheels are used in many industries. Because of many advantages such as bonding strength, long life, wear-resistant ability and high grinding efficiency. So they are widely used to machine difficult-to-cut materials such as engineering ceramics, optical glass and hard alloy. Due its high hardness, it is very difficult to true and dress diamond wheel. Wang proposed EDM dressing for abrasive grinding wheel[1]. Klocke has done experiments on truing of diamond grinding wheels to investigate the effects of truing speed ratio, and diamond grit size in the grinding wheel on the wear of truing disk [2]. Several research scholars have tested that the single diamond dresser wears out very quickly and the worn-out dresser cannot produce sufficient protrusion of the cutting grain edges [3–5]. The electrical discharge machining EDM) process has been applied to generate the precise form on metal bond diamond wheels using either the die-sink or wire EDM configurations [6–11].
The used workpiece was a grinding wheel. Table 1 shows characteristics of grinding wheel. An Electrode was copper tungsten (CuW). The diameter of the electrode was 10 mm and a depth of cut was 0.5 mm. Negative polarity was selected for an electrode due to it gives more efficient than positive polarity for EDM truing [7,8].

Table 1
Grinding wheel specifications

<table>
<thead>
<tr>
<th>Grinding wheel</th>
<th>Column A (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain</td>
<td>Diamond 1</td>
</tr>
<tr>
<td>Grit size</td>
<td>#120–#140</td>
</tr>
<tr>
<td>Bond</td>
<td>Metal bond</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>150</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>6</td>
</tr>
<tr>
<td>Concentration</td>
<td>100</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION

The EDM efficiency was considered by evaluating the Material Removal Rate (MRR) and Electrode Wear Ratio (EWR). Relationship between discharge current and MRR using TP and SC circuit can be seen in Fig.2. The experiment was set at discharge duration \( t_e = 16, 32, 64 \mu s \) and Duty factor (DF) =50 %. Both TP and SC circuit are same trend. The MRR increased with increasing of discharge current due to the increases of the energy per pulse causes temperature raises sharply that leads to rapid melting of work piece material at sparking area. [12]. And also higher pulse duration increased MRR for all peak current used. With a pulse duration at 32 \( \mu s \), the MRR start decreases when discharge current is more than 10 A.

The highest MRR is achieved at 15A of peak current and 64 \( \mu s \) of pulse on with value approximately 3.94 \( \text{mm}^3/\text{min} \). Fig 3 showed EWR using TP and SC circuit. When increase discharge current, EWR was decreased. Normally, EWR relates to discharge energy and machining time. If higher discharge energy make much shorter machining time. The EWR may be reduced. When discharge current 10 and 15 A with discharge duration 64 \( \mu s \). Some debris were cumulative deposited on the electrode resulting in the electrode was longer than original length. Longer pulse duration tends to increase the possibility of debris deposition on the electrode surface. [12]

When compare the circuit that gives the highest MRR at 15A of peak current and 64\( \mu s \). The SC circuit gives lower EWR, consequently SC circuit was selected for EDM the grinding wheel. However, the EDM process for truing not only need the highest MRR but also the profile after machining and the protrusion of diamond tip from the material surface are also needed. The lowest discharge current was interesting, so the integrity of the surface were investigated. Fig. 4 shows Scanning Electron Microscopy (SEM) of the differences in crater size for the short and long discharge pulse. EDMed surface with discharge current \( I=3A, t_e=16 \mu s \) was compared with \( t_e=128 \mu s \). When the discharge duration is long \( t_e=128 \mu s \), then the spark are more continue, as a result, a spread melted materials on the surface of the work piece are produced, hence the diamond grits are difficult to find comparing with the shorter pulse (Fig. 4a), some diamond grits are clearly seen on the surface. And this result confirms that a smaller current and smaller pulse duration should be adopted for EDM truing finishing [1].

a) TP circuit
b) SC circuit

\[ \text{Fig. 2. Relationship between discharge current and on time to material removal rate using a) TP circuit and b) SC circuit.} \]

In order to confirm the diamond grit and investigate the elements for melted materials in Fig.4. Fig.5 shows Energy dispersive X-ray spectroscopy (EDS) of point 1 and point 2 in Fig.4(a).

a) TP circuit

\[ \text{Fig. 3 Relationship between discharge current and on time to electrode wear ratio using a) TP circuit and b) SC circuit.} \]

b) SC circuit

\[ \text{Fig. 4 EDMed surface using a) } I=3A, t_e=16 \, \mu\text{s}, \text{ compared with b) EDMed surface using } I=3A, t_e=128 \, \mu\text{s.} \]

Results of EDS analysis showed that the material chemical compositions of diamond wheel surface are different in elements C, Cu, Sn and Co by weight. The element C weight percentage was found on diamond wheel surface after truing. At the point 2, carbon is clearly seen at the peak. This may be caused by high temperature in EDM and carbon in diamond may diffuse or melt.
Fig. 5  EDS analysis in Fig.4(a) at point 1 point 2.

Fig.6 shows distance of the diamond tip and metal bonding surface. The figure shows side view for EDM dressing using 3 conditions finishing: I=3A, t_e=16 µs, semi-finishing: I=5A, t_e=64 µs and roughing: I=15A, t_e=64 µs. From the Fig.6, roughing gives the highest value of protrusion of diamond tip: 0.055 mm followed by semi-finishing: 0.032 mm and finishing: 0.023 mm.

a) I=3A, t_e=16 µs

b) I=5A, t_e=64 µs

c) I=15A, t_e=64 µs.

Fig. 6  Protrusion distance of EDM dressing for grain wheel using  a) I=3A, t_e=16 µs, b) I=5A, t_e=64 µs and c) I=15A, t_e=64 µs.

A multi-EDM grinding process is adapted to fabricate a diamond grinding wheel. Equipments such as an copper tungsten electrode bar, EDM machine and a spindle head are used for EDM machining. The electrode bar of copper tungsten was cut to be desired profile. Fig.7 shows a schematic of the experiment. The diamond wheel was drived with spindle 300 rpm.
For EDM truing, the highest high machining speed is required and smooth surface finish also is needed. Consequently, EDM dressing processors are made with distinguishing for rough machining, for semi-finishing and for finishing. Fig.8 shows image of truing with rough, semi-finish and finish. Fig.8 shows image of truing with rough, semi-finish and finish. Rough machining emphasizes machining speed. The process need to machine all surface. Table 2 shows the EDM truing conditions. The experiments were carried out with 3 conditions. Roughing was used with discharge current 15 A and \( t_e = 64\mu s \). The workpiece was fed toward the electrode. The machining time depended on profile curve of the workpiece or diamond wheel. For this step used 45 minutes, wear electrode was 140 \( \mu m \). Semi finishing is designed as an intermediate step reduction between a rough electrode and a finish electrode. This step is required for forming a profile of the wheel’s shape. We used 15 minutes for this process and wear was 98 \( \mu m \). Finishing attaches great importance to machining accuracy, machining surface roughness and protrusion of diamond must be generated. Finishing needs 15 minutes for this process and wear is 98 \( \mu m \).

### TABLE 2

<table>
<thead>
<tr>
<th>Process</th>
<th>Parameters</th>
<th>Machining time (min.)</th>
<th>Wear (( \mu m ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough</td>
<td>( I = 15 A, t_e = 64\mu s )</td>
<td>45</td>
<td>140</td>
</tr>
<tr>
<td>Semi Finish</td>
<td>( I = 5 A, t_e = 64\mu s )</td>
<td>15</td>
<td>98</td>
</tr>
<tr>
<td>Finish</td>
<td>( I = 3 A, t_e = 16\mu s )</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

Fig.9 shows wheel profile before and after truing. Wheel profile has a profound effect on grinding performance as characterized by surface finish. In this study, the wheel profile after truing has been measured using a profile meter. It can be seen that the variance between maximum and minimum in the curve is near to the original curve.

**CONCLUSIONS**

1. EDM truing can achieve on an abrasive grinding wheel while SC circuit gives material removal rate (MRR) quite same as TP circuit. But SC circuit gives electrode wear ratio less than that EDMed with TP circuit.

2. MRR increases with increasing of discharge current. And discharge current trend is same as discharge duration.
3. Finishing process of EDM truing can be succeeded with \( I = 3A, t_e = 16 \mu s \) that give more protrusion distance than EDMed surface using \( I = 3A, t_e = 128 \mu s \).

4. The truing accuracy of EDM truing can be accepted with profile of grinding wheel.

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REFERENCES


