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Fabrication of high aspect ratio micro electrode by using EDM

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Abstract. The electrical discharge machining (EDM) process inherits characteristics that make it a promising micro-machining technique. Micro electrical discharge machining (micro-EDM) is a derived form of EDM, which is commonly used to manufacture micro and miniature parts and components by using the conventional electrical discharge machining fundamentals. Moving block electro discharge grinding (Moving BEDG) is one of the processes that can be used to fabricate micro-electrode. In this study, a conventional die sinker EDM machine was used to fabricate the micro-electrode. Modifications are made to the moving BEDG, which include changing the direction of movements and control gap in one electrode. Consequently current was controlled due to the use of roughing, semi-finishing and finishing parameters. Finally, a high aspect ratio micro-electrode with a diameter of 110.49μm and length of 6000μm was fabricated.

1. Introduction
Electrical discharge machining (EDM) is non-traditional machining process which depends on thermoelectric energy between two electrodes. During this process, a series of discrete discharges are used to remove the material electro thermally between two electrically conductive parts that are electrode and work piece. The performance of this process depends on the design of material, and manufacturing method of the electrodes [1]. Micro electrical discharge machining (micro-EDM) is a derived form of EDM, which is commonly used to manufacture micro and miniature parts and components by using the conventional electrical discharge machining principles [2]. Major differences of micro-EDM from conventional EDM have been in the type of pulse generator, the resolution of the X-, Y- and Z- axes movement, and the size of the tool used. Main functions of micro-EDM are micro-mold making, production of die and cavities and complex three-dimensional shapes in micro level [3]. Micro-EDM machines have been used in many researches for the fabrication of micro-electrode [4, 5, 6]. This study attempts to fabricate micro electrode by controlling the gap, current, and direction of movements in moving BEDG and subsequently drill micro holes on AL6061-% 0.5Ce using the EDM machine

2. Literature Review
Baoguoet al. [7] fabricated micro-electrodes with two different methods that involved micro electrical discharge machining (EDM) and electrochemical machining (ECM).The micro-electrode was fabricated with a counter block of EDM. The original electrode used tungsten filament with diameter...
500μm. The final electrode was fabricated successfully after several repeated machine steps with the diameter 5.5μm, and length 40μm. Micro-electrode with the diameter 7μm was fabricated by ECM when the machining parameters were set to 8V as machining voltage, 2μs as pulse on time, and 200 KHz as frequency [7]. Hourmand and Noordin [8] fabricated micro electrode based on modified moving block electro discharge grinding process. The modification involves changing the direction of movement and control gap; and the use of roughing, semi finishing and finishing electrodes in one electrode. High aspect ratio micro electrode with diameter of 165μm was successfully fabricated using a conventional EDM instead of a micro-EDM. Stationary sacrificial block electro discharge grinding (BEDG), rotating sacrificial disk, wire electro-discharge grinding (WEDG), moving block electro discharge grinding (moving BEDG), micro turning process; and hybrid of micro-EDM and micro turning process are the processes that can be used for fabricating micro-electrode from an electrode thicker than the required electrode [5, 6]. Figure 1(a) illustrates BEDG as one of the simplest methods for on-machine fabrication of micro-electrode. Figure 1(b) depicts a rotating disk electrode which is 0.5mm thick, 60 mm in diameter and 90 rpm in speed and being used as a rotating sacrificial disk. Figure 1(c) shows a guided running wire with a diameter of 0.07mm and speed of 3-5 mm/s being used as an electrode in WEDG [5]. Figure 1(d) and (e) depicts how the EDM gap is controlled in the Z-axis and relative translational motion between the tool electrode and the sacrificial block in moving BEDG.

![Figure 1. Types of the sacrificial electrode for on-machine tool fabrication (a) stationary sacrificial electrode (b) rotating sacrificial disk (c) guided running wire [5] (d) at the beginning of moving BEDG (e) groove created by erosion of moving BEDG [6]](image)

3. Fabrication of Microelectrode by EDM

The experiments have been conducted on AG40L die sinker Electrical discharge machine as shown in figure 2(a). The copper was selected as the material for both electrode and workpiece, because copper has good machinability, low price and produce fine surface finish. The copper block electrode with two slots was fabricated by mill machining to be used as workpiece. The electrode was machined initially by lathe machine to reduce the diameter from 6mm to 1mm before it was used as the electrode in EDM machine for reducing its diameter to micro-scale/dimension. The most important step for fabricating the micro-electrode is the alignment process for the copper block because if the alignment process is inaccurate, the micro electrode will have taper and cannot be used. As a result, alignment process was done by using the tool shown in figure 2(d). The micro-electrode cannot be removed from the machine to measure the diameter after each experiment. For that, new clay as shown in figure 2(c) was used to measure the diameter without removing the electrode.
4. Machining Parameters and CNC Program

EDM process is a slow process and depends on the current. If the current is high, the process will be fast, but surface finish will not be good. In this study three current values were applied. Table 1 illustrates the parameters that were used. 18 (006.0)Ampere was initially applied to make the process faster, but the surface was roughing. To get a semi-fine surface, the current value was adjusted to 9Ampere (003.0). Finally, 0.4 Ampere (000.1) was applied to get high quality surface. Figure 3(a) and (b). show the directions of cutting processes, Y axis determines the amount that will be removed from the electrode; while Z axis will control the length from the electrode; X axis is used for controlling the EDM gap between the ZY surface (side surface) of the sacrificial block electrode and the electrode tool.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value /(unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity</td>
<td>-</td>
</tr>
<tr>
<td>Pulse on time</td>
<td>600/ (µs)</td>
</tr>
<tr>
<td>Pulse of time</td>
<td>45 / (µs)</td>
</tr>
<tr>
<td>Peak current</td>
<td>18,9,0.4/(A)</td>
</tr>
</tbody>
</table>

Table 1. EDM machining parameters.
5. Conclusion
In this paper, the processing steps for fabricating a micro-electrode using an EDM machine based on block electro method process was explained. The fabrication processing steps were simple and do not require high investment for special equipment. Finally, high aspect ratio micro electrode with the diameter of 110.49μm was successfully fabricated using a conventional EDM. A micro-holes of size 198.78μm and 175.54μm were successfully produced with the micro-electrode.

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References