International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 3, May-Jun-2023, ISSN (Online): 2395-566X

Divisional Production of Micro-Electrodes by Electric Discharge Machining and It's Performance Evaluation

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Abstract- Micro-EDM is widely used in micro-holes and 3D microstructures. However, micro-EDM applications are limited due to their rarity. Therefore, microelectrode fabrication is one of the most challenging and hot topics in the EDM field. In this study, EDM is used in the fabrication of microelectrodes. Parametric testing is necessary to ensure high dimensional accuracy of microelectrodes. It is performed by replicating a 1 mm diameter copper electrode on a steel block using a segmented fabrication method. A relationship is established between the excavated cavities of the block and the function of the microelectrodes. Editing effect of parameters (current, pulse width, and pulse pause) is seen on response variables (electrode underside length, electrode length, material removal, velocity, surface roughness and lateral deviation rate). Current and pulse width dominate over otherselected process parameters. Using parameters optimized from parametric studies, copper microelectrodes with a bottom length of 40 µm and a length of 1700 µm is produced. A 1100 µm long, 80µm wide and 30µm deep microchannel was machined on the copperseat.

Keywords- Micro-EDM; Divisional Production; M.R.R.; Surface Roughness; Length Deviation Factor

I. INTRODUCTION

Micro electric discharge machine, a kind of micro fabrication technology to know Machining microstructures and realizing their properties to overcome strength with softness for processing of conductive materials which is difficultto manufacture [1-2]. in the past few years,More and more microelectrodes are in demand due to the fact that the microelectrode is one of the most importantpart of Micro EDM and loss of it occurs inMicro-EDM [3].In the method of online production of electrodes, wiresElectrode discharge grinding and block electrode discharge grinding are commonly used. [5].

Japanese since 1984 Scholar Takaaki Masuzawa and others use wire electrode discharge Polishing equipment for microelectrode processing2.5 µm in diameter [6]. In recent years, scientists have continued to studyfor manufacturing of microelectrodesin two aspects: WEDG which is mostly combined with othersto achieve high-efficiency and high-precision processing of micro electrodes [9]. BEDG is to improve the quality of microelectrodes. Parameter optimization and feed angle change Block electrodes [10-12]. But whichever wayThere is a lot of research on cylindrical manufacturing.There is little research on the fabrication of electrodes, andOther shaped electrodes. In this study, based on EDM, a segmented method Manufacturing is used to study square preparations electrode. Effects of processing at the same time parameters for the parameters of the tested microelectrodes,In order to reduce the side length deviation rate,Decrease bottom length, increase length, reduce surface roughness, and finallymaterial removal rate.

II. EXPERIMENT

Japanese Sodick AD30Ls Square Drive EDM Machine Wave pulse generator and EDM-1 oil are used for processing experiment. Experimental details are shown in Table 1.In conventional machining, tool materials are usuallyhigh speed steel or carbide used [13]. But, EDM is a kind of non-contact machining at lowcutting force and its main property is "Overcome strength with softness". Which do not raise the need of electrodes that require hardness? A common material for EDM electrodes is copperIn addition to being excellent in conductivity and heat resistance; there are also economic benefits [14]. C45 was chosen as workpiece material for this experiment which is designed with a 1 mm diameter tool electrode, with25mm×25mm×2mm steel plate.

Table 1. Experimental details.

Projects	Conditions
Tool Electrode	Copper (1mmdia.)
Workpiece Material	C45(30mm×30mm×2mm)
Dielectric Fluid	EDM-1oil
Processing Polarity	-
Flushing Condition	Lateralflushing
Peak Voltage	90V

Dimensional accuracy and shape accuracy are challenging in the production of microelectrodes by EDM. The length of one side of the electrode of bottom surface is controlled by increasing the diameter of the steel channelSeat due to lateral spark. The electrode length isaffected mainly by electrode and tipdischarge effect is the main reason for axial loss ofmicro electrode. Always the first part of metal in machining erodes more material than later machined parts. The first machined part of the electrode is smaller than that part processed after first.It may cause unevenness of the electrode.

To avoid the above problems as much as possible, it uses a split manufacturing method, So that aspect ratio and uniformitymay be maximized as much as possible. Not only that, segmentation Craft can also eject debris easily in spark gap which will increase material removal rate.Figure 1 shows the first stage of split production. Before machining, the electrode is at the origin. First, Electrodes move in the positive direction towards the X axisAt X0.44 move to Y2.1 in the positive direction of the Y axis.

Then move the Z axis in the negative direction towards Z-2.2.Edit the U0° surface. After processing is completed, the electrode will return to the Z0 position. Finally, move the electrode to rotateY4U180°, Y6U90°, Y8U270°, repeat the above feeding path at each position to complete the process Machining the remaining 3 sides. At this point the firstA phase of segmented processing is declared complete.

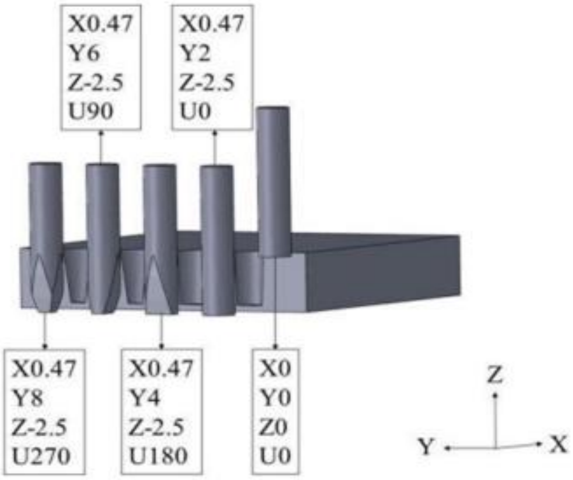

Fig 1. Schematic of the first stage of segmented manufacturing.

The second stage of processing is shown in Figure 2.The electrode travels along the Y axis to Y10, Then feed to Z-2.5 in the negative Z direction.The electrodes then continue to advance in the negative directionfrom the Z axis to Z-5 while feeding the electrode a little (x1) Positive direction of the x-axis to achieveelectrode uniformity as much as possible. During processing, the electrode returns to Z0 accordinglyto original position. Finally, move the electrode to rotateit to Y12U180°, Y14U90°, and Y16U270 °, repeat the above feed path at each position to complete the processMachining in remaining 3 sides. FinallyElectrode machining process completes.

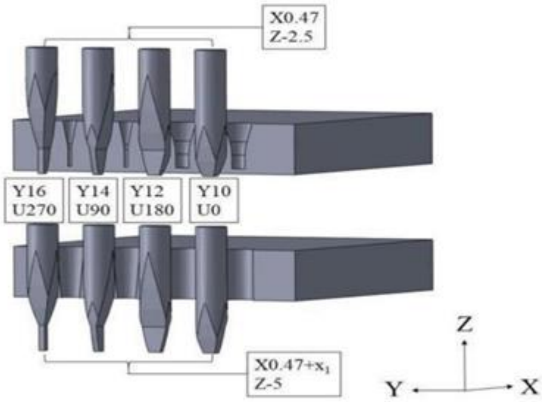

Fig 2. Schematic diagram of the second stage of segmented manufacturing.

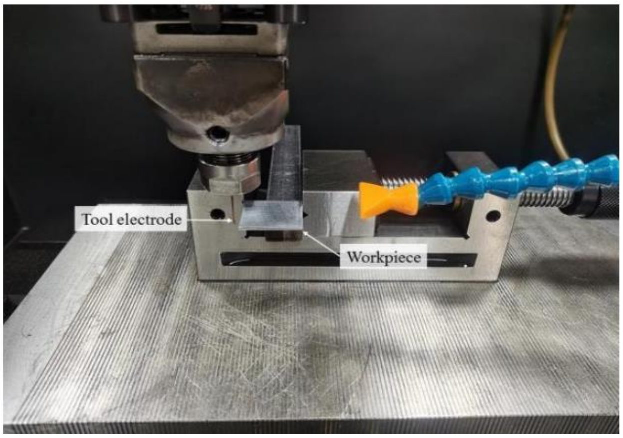

Fig 3. EDM machine for micro-electrode processing experiment.

The test setup is shown in Figure 3. Decide influence of processing parameters on the underside of the electrodelength, metal removal rate, surface Roughness and Transverse Deviation, Orthogonal. The experimental design is based on the Box-Behnken designby design experts. Current, Pulse Width, Pulse Intervalare selected as independent parameters and their values areshown in Table 2. After creating each electrode Flattening of the bottom surface of the electrode by EDG machiningreduces the influence of the electrode on the subsequent processing microchannel.

Table 2.Processing parameters and values.

Parameters	Low	Middle	High
Current(A)	6	9	12
Pulsewidth(μs)	1	2	3
Pulseinterval(μs)	10	20	30

Before processing the experiment, electrode was measured using an electronic analytical balance.After the treatment attempt, the weight of copper electrode was measured using an electronic analytical balanceand the processing time was logged. Weight difference was calculated before and after each copper electrode treatment experiment. And broken down by treatment times to get the material removal rate for each microelectrode in gm/min.. The schematic diagram of the electrode isin Fig. 4.A digital microscope was used to collect the 3D imageof the electrode for measuring the bottom edge length L of electrode lengths.

Roughness of the electrode surface was obtained simultaneously from optical imaging. For Reliability of measurement, all Ra values are taken. The central axis of the side electrode, as shown in fig.The lateral length deviation coefficient should be obtained by calculating the difference between the side length of the base of the electrode andthe length of the lower edge of the electrode by subsequently dividing this difference for electrode length, for example formula

Side deviation rate = (lr-lb)/l

in this formula, lr➔ represents electrode root side length, lb➔represents electrode bottom side length, l represents electrodelength.

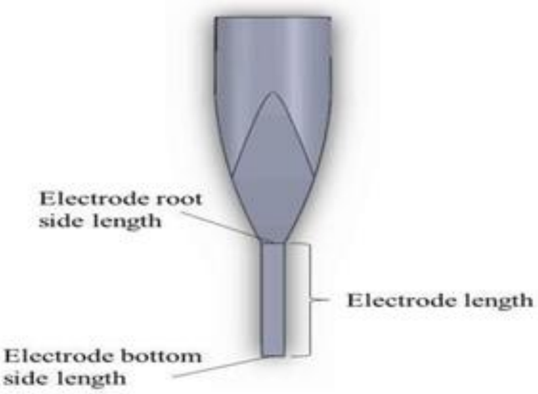

Fig 4. Schematic diagram of electrode.

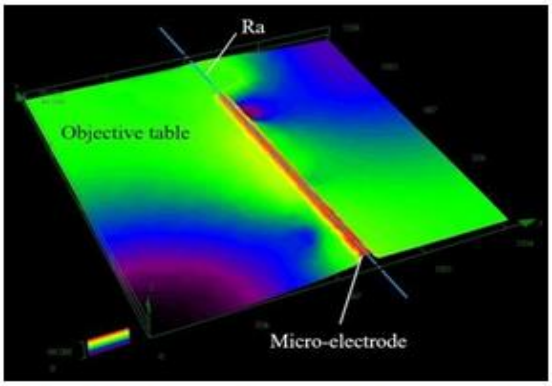

Fig 5. 3D image diagram of the electrode.

III. RESULTS AND ANALYSIS OF THE EXPERIMENTS

1. Analysis of variance:
Analysis of the deviation table shows this contribution of each independent parameter to the response. The variableis drawn (Table 3). For factors with a 95% confidence level with a p-value less than 0.05 are considered significant.No match, correct R2 values and expected R2 values areused to evaluate the model's usefulness for prediction response. For all answers, for lack of Fit is not significant (p-value > 0.05), corrected for R2 is predicted values of R2 are close together, the difference is less than 0.2.Of course, this model is suitableforanalysingthe process parameters. You can see it from Table 3 that current and pulse width are important factors affecting the quality of the microelectrode while Thepulse interval is a secondary factor.

Table 3. Influencing factor of the selected parameter.

Response variable	% Contribution		
	Current	Pulse width	Pulse interval
Electrode bottom side length	63.95	35.97	0.08
Electrode length	98.74	0.69	0.57
Material removal rate	45.54	54.43	0.02
Surface roughness	83.96	14.9	1.14
Side length deviation rate	0.16	99.6	0.24

2. The length of the bottom edge of the electrode:
Figure 6 is a graph of the interaction response surface of each factor along the length of the lower edge of the electrode. That is evident that current and pulse width are important factors affects the length of the bottom edge of the electrode. The amplitude of the pulse is the second important factor, which affects the length of the bottom edge of the electrode. With pulse Width increases by, material is removed in one pulse increases and the length of the lower edge of the electrode decreases. Although increasing the pulse spacing may result in more complete deionization of the inter electrode dielectric, it has less effect along the length of the bottom of the electrode as current and momentum wide.

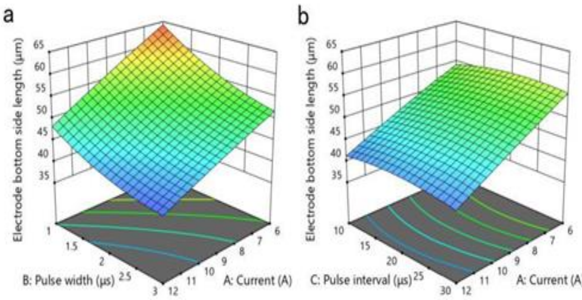

Fig 6. Effect of (a) current and pulse width (b) current and pulse interval onthe electrode bottom side length.

3. Electrode length:
The length of the electrode is another important parameter of Electrode size. it can be seen that with regard topulse width and pulse pause, the current has a larger effect on Electrode Length. And why segment machining was

adopted and proper power supply to electrode is in the positive direction of the X-axis was obtained from many experiments, hence the axial loss. The electrodeis generally avoided, at the same time segmented. The production can also increase the shape of the electrode symmetrical. At this point, an increase in current will resultplus material removal along the electrode axis, lengthens the regular part of the electrode, i.eincreases the electrode length

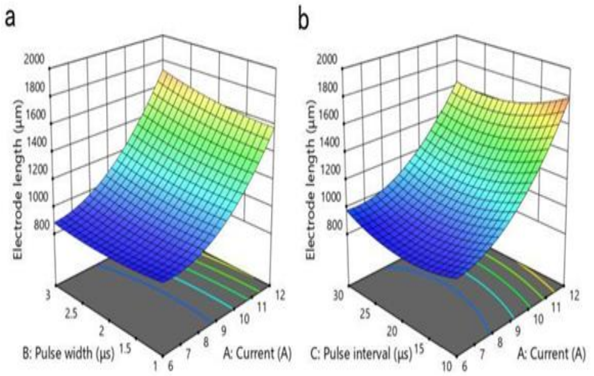

Fig 7. Effect of (a) current and pulse width (b) current and pulse interval on the electrode length.

4. Material Removal Rate:

The rate of material removal determines the efficiency of microelectrode processing. As shown in Figure 8, pulse width and current are the main factors affecting material removal rate. Increasing the pulse width increases the effective discharge time of a single pulse, thus removing more material. As the current increases the discharge energy increases and at the same time more material is removed with higher current. Whether increasing the pulse width or current, the rate of material removal rate increase.

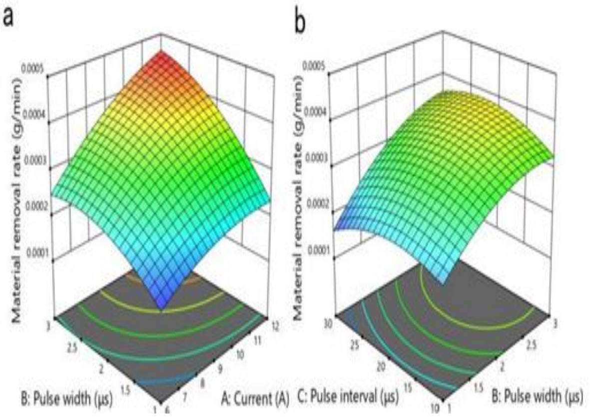

Fig 8. Effect of (a) current and pulse width (b) pulse width and pulse interval on the material removal rate.

This is because when the pulse width and current are increased.A large amount of debris is generated in the interelectrode medium, which reduces the insulation. Based on this, if the pulse width and current continue to increase, a large number of short-circuit phenomena can occur, reducing the material removal rate.

5. Surface Roughness:

The surface roughness is an important parameter that stands for the quality of the microelectrode. Thelow roughness of microelectrode can improve the in-app processing effect. The surface roughnessis greatly affected by current iand pulse width. Increasing current increases discharge energy and increasing pulse width increases the effective discharge time of a single pulse that results in larger crater size when processed. The surface of theEDM part consists of countless craters, larger craters that increase the surface roughness. Increasing the pulse interval helps in removing contamination Workspace that improves working conditions between electrodes and allows the fresh surface to participate in the process sparks later. However, the pulse range has little affects on the surface roughness

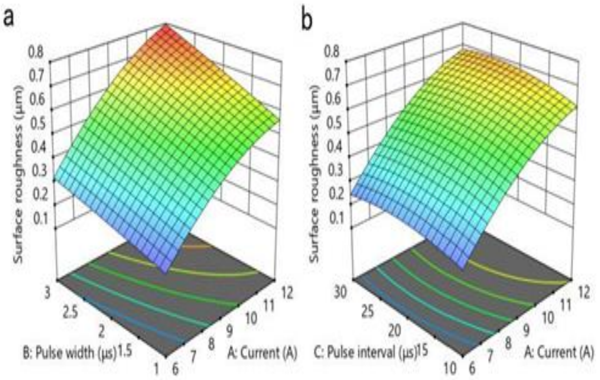

Fig 9. Effect of (a) current and pulse width (b) current and pulse interval on the surface roughness.

6. Lateral length variation coefficient:

The lateral length deviation factor is an important parameter that reflects the homogeneity of the microelectrode. Segmented manufacturing aims to minimize side length deviation factor. This is from Fig.10, as pulse widthis the most important factor for lateral length deviation.As the pulse width increases, the diameter of the whole lights upsteel plate increases and subsequently makes machined partsno longer worked sufficiently; hence the deviation coefficient of the side length increases. Theoretically, a rising current also increases Length Deviation Factor. However, in the second stage Treatment, electrode feed suitable perpendicular to the machined side of the steel sheetply wood, so the reworked part removes High Energy Material. Use segmented production essentially avoids the impact of the current on the homogeneity of the microelectrodes.

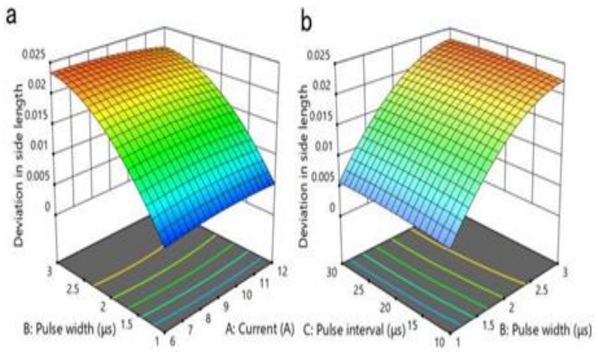

Fig 10. Effect of (a) current and pulse width (b) pulse width and pulseinterval on the side length deviation rate.

7. Parameter Optimization:
In EDM microchannel machining, the uniformity of theelectrodes has a major impact on Microchannel geometry. In long size electrodes, the rate of deviation from length causes uneven width. Hence make sure of homogeneity of the electrode, i.e. the lateral length deviation coefficient occupies the highest weight. When eroding the microchannel in EDM depends on the roughness of the surface of microelectrode and high aspect ratio electrode allows you to process larger micro channels, e.g.most wide spread.Compared to above factors directly affecting geometry and quality electrode, material removal rate affects the performance of electrode production and does not affect the following micro channel processing. Summary of material removal Rate gets lighter weight and the lighter weigh tside length, electrode length and surface roughness between the rate of deviation of the side length and the rate of stock removal.

Minimize the length of bottom edge of electrode, maximize the electrode length, maximum material removal rate, minimizes surface roughness and minimizes side length as constraint. Adjust the weight of the page length deviation to 10, the weight of the bottom of the electrode, electrode length and surface roughness up to 1 wtmaterial removal rate to 0.1 and accept the result e.gthe highest expected value. At current = 12 A, pulse width = 1 µs, pulse interval = 10 µs, low-side microelectrode length = 45.70 µm, electrode length = 1758.52 µm material removal rate = 2.1107 x 10 -4 g/min, surface roughness Ra = 0.4838 and side length variation factor = 0.0046 can be worked to a desired value of 0.710.

IV. MANUFACTURE AND USE OF MICROELECTRODES

Using the best combination of parameters found inprevious section, Microelectrode fabrication experiment were made and the squareelectrode was successfully producedwith lower side length 46µm, length1773 µm, surface roughness 0.493 µm and lateral length deviation factor 0.0045, as shown in Fig. 11

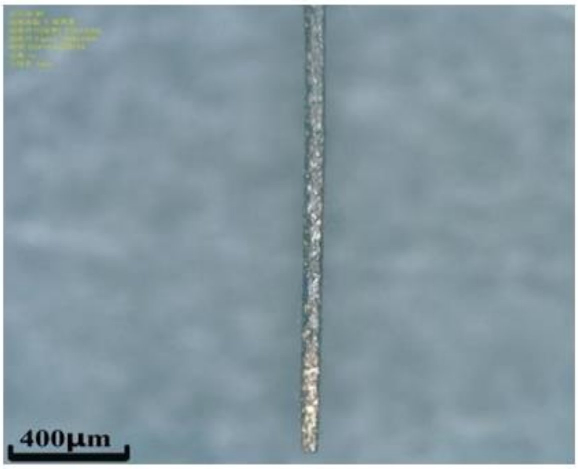

Fig 11. Micro-electrode fabricated using the optimum process parameters.

Use of this microelectrode for treatmentexperiments with copper foil, microchannel lengthwith a thickness of 1200 µm, a width of 85 µm and a depth of 35 µm.successfully treated as shown in Fig. 12.

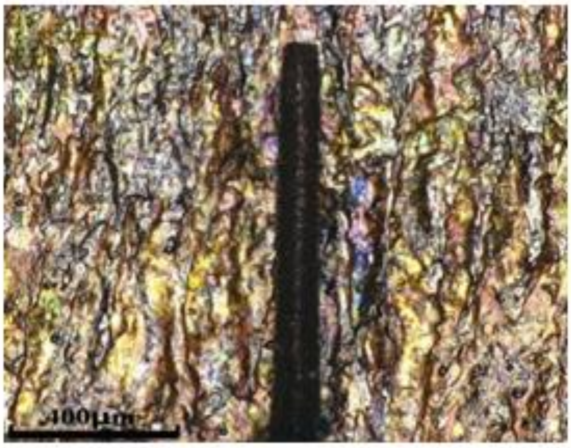

Fig 12. Micro-channel machined on copper sheet.

V. CONCLUSIONS

Current and pulse width are the main factors that determine the quality of the electrode, and the pulse spacing has little influence. Current = 12 A, pulse width = 1 µs, pulse spacing = 10 µs was found to be the optimal level of the selected process parameters to obtain a microelectrode with a short side length = 45.70 µm, length = 1758.52 µm, stock removal rate = 2.1107 x 10 & supmin; & sup4; g/min, surface roughness Ra = 0.4838 and lateral length variation factor = 0.0046.

Square electrode with bottom length 46 µm, length 1773 µm, surface roughness 0.493 µm and 3. A square electrode having a bottom side of 46 µm, a side of 1773 µm, a surface roughness of 0.493 µm and a side length deviation of 0.0045 was prepared. This square the electrode took 83 minutes to fabricate. When using microelectrodes, a microchannel of 1200 μm length, 85 μm width and depth35μm was processed on copper foil.

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