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FABRICATION OF MICRO ELECTRODES FOR EDM AND OPTIMIZATION OF THE PROCESS PARAMETERS FOR MAXIMUM MACHINING RATE (MR)

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Abstract - *Electrodes are the most essential component in Micro Electrical Discharge Machining (Micro-EDM). Electrode wear affects the geometry and precision of the components. In present work, a new technique has been adopted to fabricate micro electrodes in rectangular metallic materials using tubular electrodes in EDM process. Micro electrodes with high aspect ratio were generated in rectangular copper block using tubular electrodes of copper in electrical discharge drilling (EDD) process. Machining rate (MR) has been investigated on EDD process using Taguchi's L9 orthogonal array. The process parameters namely Discharge current (I_p), Pulse-on time (T-on) and Pulse-off time (T-off) are used for investigation. In order to optimize process parameters for maximum machining rate, Taguchi's approach has been used in the present research work.*

Key Words: Micro electrodes, Micro EDM, Machining Rate, EDD, electrode material.

1. INTRODUCTION

Electrical Discharge Machining (EDM) Drilling is quickly becoming the standard method for producing small, tight tolerance holes. It is an extremely cost-effective method for producing fast and accurate holes into all sorts of whether hard or soft conductive materials. Electrical Discharge Machining (EDM) is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode and a workpiece in the presence of a dielectric fluid. EDM is based on the erosion of electrically conductive materials through the series of spatially discrete high-frequency electrical discharges (sparks) between the tool and the workpiece illustrates that each spark occurs between the closest points of the electrode and the workpiece. The spark removes material from both the electrode and workpiece, which increases the sparking gap (distance between the electrode and the workpiece) at that point. This causes the next spark to occur at the next-closest points between the electrode and workpiece. As EDM is a thermal process, material is removed by heat. Every discharge (or spark) melts a small amount of material from both of the electrodes. Part of this material is removed by the dielectric fluid and the remaining solidifies on the surface of the electrodes.

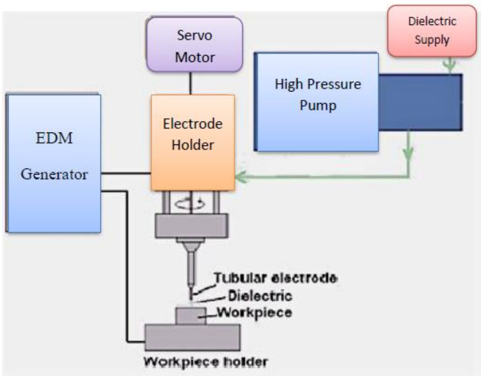
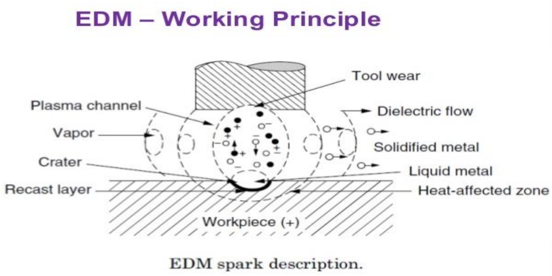


Fig. 1 Electrical Discharge Drill machine

1.1 WORKING PRINCIPLE



Working principle is same as EDM In this process the material is removed from the workpiece due to rapid sparking occurring between the tool electrode and workpiece. A small gap about 0.025-0.075mm is to maintained between the tubular electrode and the workpiece. Dielectric fluid of simple tap water is continuously supplied at high pressure through the hollow electrode to flush the eroded particles out of the drill hole. The temperature due to sparking is rise above 10,000 0C in the spark gap, as a result of material get vaporized. The sparking takes place at the bottom of the electrode and electrode wear takes place primarily at the bottom edge of the electrode as shown in fig.1.5. In addition to that the secondary discharges material removal takes place between the electrode and top edge of the work material.

1.2 IMPORTANT PARAMETERS IN EDD

(1) **Spark On –time (Ton)**: The duration of the time the current is allowed to flow per cycle. The amount of energy applied during the cycle is directly proportional to pulse on time. This energy is really controlled by the peak current and the length of the on-time.

(2) **Spark Off-time (Toff):** It is time duration between the successive sparks. The time which allows the molten metal solidify and to be wash out of the gap. This parameter affects the speed and stability of the cut. Thus, if the off-time is too short, it will cause the sparks to be unstable.

(3) **Arc gap (or gap):** It is the gap between the electrode and workpiece during the process of EDM. It may be called as the spark gap. Spark gap here is maintained by the servo system.

(4) **Discharge current (Ip):** Discharge current is very important parameter here which controls the material removal rate.

(5) **Electrode polarity**: Polarity refers to an electrical condition determining the direction of the current flow relative to the electrode.
Straight polarity: Electrode (-) & work-piece (+)
Reverse polarity: Electrode (+) & work-piece (-)

1.3 TOOL (ELECTRODE) MATERIAL

Tool material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.
The basic characteristics of electrode materials are:

• High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating.

• High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear.

• Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy.

• High melting point – high melting point leads to less tool wear due to less tool material melting for the same heat load.

• Easy machinability.

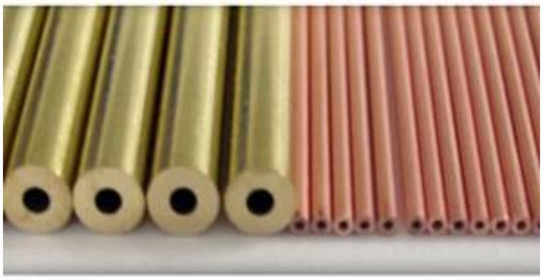


Fig. 2 Tubular electrodes

2. EXPERIMENTAL RESULTS FOR MACHINING RATE (MR)

Here the experiments carried on the copper workpiece using the copper tubular electrode having outer diameter 2 mm and inner diameter 0.9 mm. This study has been done on three experimental input parameters Current(Ip), Pulse on time (T-on), Pulse off time (T-off). So According to this approach Experiments have been done using three level and three factors. For this L9 array has been used to process the parameters. The depth has been taken 20 mm.

Table -1: Process parameters selected for present work

	Process parameters	Level 1	Level 2	Level 3
A	Discharge current(Ip) (Amp.)	3	4	5
B	Pulse-on time(μs)	5	6	7
C	Pulse –off time(μs)	4	5	6

The process parameters have been decided for experiments on EDD machine using tubular electrodes as shown in fig. 2

having rotation of 145 rpm for fabricating the micro electrodes for EDM of high aspect ratio.

Table -2 Results for Machining Rate of micro electrodes

Exp No.	Ip	Ton	Toff	M/cing Time min	L mm	MR mm/min
1	3	5	4	13.57	18.40	1.356
2	3	6	5	11.39	18.95	1.663
3	3	7	6	14.56	16.88	1.259
4	4	5	5	6.33	13.54	2.140
5	4	6	6	6.15	17.85	2.900
6	4	7	4	5.51	18.35	3.33
7	5	5	6	5.19	17.20	3.314
8	5	6	4	3.59	17.45	4.860
9	5	7	5	4.16	17.55	4.218

Table-3 Analysis of variance (ANOVA) Table for MR

Source	**DF**	**Adj SS**	**Adj MS**	**F value**	**P**
Ip	2	10.9731	5.48655	1292.34	0.001
Ton	2	1.2439	0.62196	146.50	0.007
Toff	2	0.7693	0.38463	90.60	0.011
Error	2	0.0085	0.00425		
Total	**8**	12.9948			

Results for MR were analyzed using ANOVA to find significant factors which are affecting response factor i.e. MR. ANOVA table for machining rate is generated for 95% confidence interval. F-test is also performed on the data to find contribution of each factor. The principal of F-test is that the larger the value of F more is the effect on response variables or in other words more is the contribution. For 95% confidence interval a factor is said to be significant if F-value is greater than the table value and P value is less than 0.05. Hence, significant results are found for Machining rate of micro electrodes.

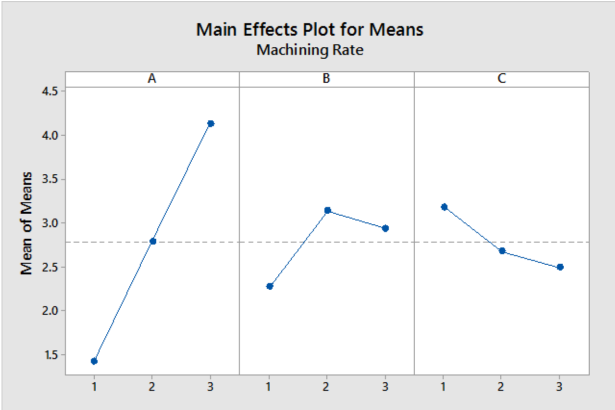


Fig.3: main effects plot for means of MR.

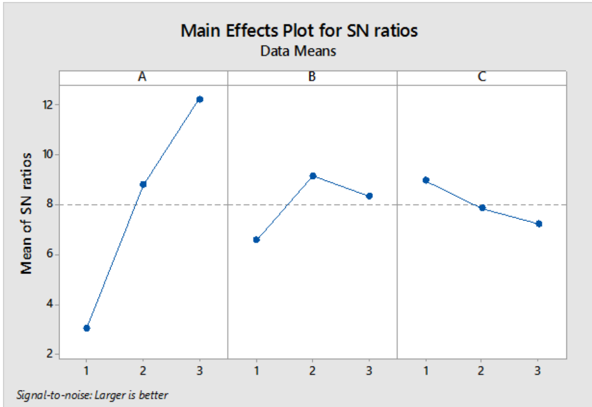


Fig.4 Main effects of plot fot SN ratio of MR

From SN ratio graph for MR as shown in Figure 6.2, the optimized values for maximum MR are:

- I_p = A3 = 5 Amp.
- T_{on} = B2 = 6 µs
- T_{off} = C1 = 4 µs

In order to predict the optimal values of the machining characteristics, only significant parameters are included which were found utilizing analysis of variance (ANOVA). The optimal values are predicted using the following relationship,

$$\eta_{opt} = \eta_m + \sum_{i=1}^{q}(\eta_i - \eta_m) \quad \text{.........(i)}$$

where η_m is the total mean of the machining characteristic under consideration; η_i is the mean values at the optimum level (from response Tables) and q is the number of process parameters that significantly affects the machining characteristics. By using equation (i) the predicted value has been calculated for MR, EWR and Taper (α).

Table-4 Optimized results for MR using Taguchi's approach

Machining characteristic	Optimal parameters combination	Significant parametes	Predicted value	Experimental value
MR	$A_3B_2C_1$	A, B, C	4.86 mm/min	4.95 mm/min

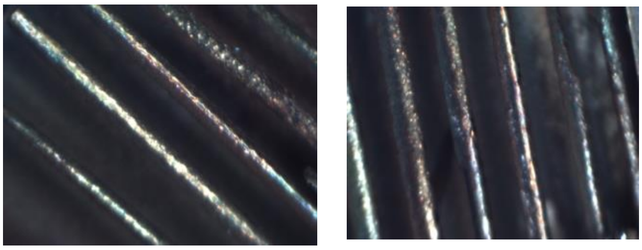


Fig -5: 3-D view under stereo zoom microscope of fabricated micro electrodes for EDM

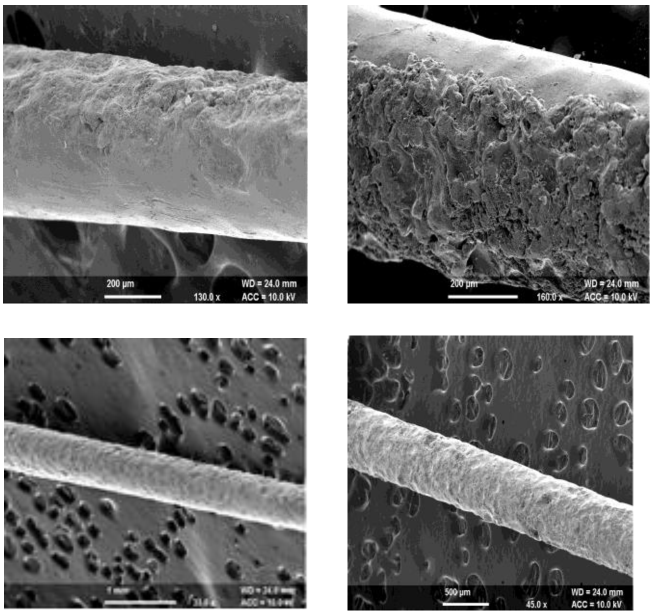


Fig.6 SEM images of micro electrodes

Recast layer has been found on the micro electrodes. Craters also have been investigated on the surface of micro electrodes. The recast layer or the carbon layer help to reduce the electrode wear rate in micro EDM machining.

3. CONCLUSIONS

In the present work the micro electrodes were fabricated using tubular electrodes of copper having outer diameter 2mm and inner diameter 0.9 mm on electrical discharge drilling (EDD) process. The following conclusions are obtained:

1. Machining rate (MR has been investigated on the electrical discharge drilling (EDD) using Taguchi's L9 orthogonal array.

2. The micro electrodes of Aspect ratio (length/diameter) ranging between (22.08-30.91) have been investigated. The minimum mean diameter of micro electrodes obtained is 0.581 mm and maximum length of micro electrode is obtained as 18.95 mm.

3. MR of the electrodes fabricated increases with the increase in discharge current and pulse on time, while decreases on increasing the pulse off time.

4. Recast layer has been found during the SEM on the micro electrodes which has a surface roughness on the higher side.

5. Using the Taguchi's approach the optimal combination of the process parameters for MR is observed as A3(I_p=5Amp.), B2(T_{on}=6 μs), C1(T_{off}=4 μs).

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