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Manufacturing of Brass and Copper Micro Electrodes by WEDG Process

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Abstract: *This paper deals with the manufacturing of micro electrodes by wire electrical discharge grinding process (WEDG). The copper and brass rods of Ø3mm are machined and reduced to Ø0.4mm. These rods with lesser diameter are to be used as micro electrodes for EDM process. Micro electrodes are the tools for micro hole drilling of hard materials by EDM process. In this paper the machining parameters of copper and brass electrodes were analyzed with the help of S/N ratio to find the optimal parameters for attaining the required diameter.*
Keywords: *WEDG, micro electrode, EDM, S/N ratio*

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I. Introduction

Electrical Discharge Machining (EDM) is a thermoelectric process, which erodes workpiece material by a number of discrete electrical sparks between the conductive workpiece and tool electrode, immersed in a dielectric fluid. The EDM process uses the discrete number of electrical sparks to erode the unwanted material from the workpiece to get the desired shape required. The technologies of wire electrical discharge machining (WEDM) have been found interest in the recent years and have improved rapidly in owing to the requirements in various manufacturing fields, especially in the precision die industry, aerospace, nuclear engineering and other industrial areas. Micro Manufacturing technique has increasingly attracted research interest. Initially the research was carried out the ratio between the clearance and the amplitude of wire vibration is the most appropriate value to judge the short circuit gap1. To avoid short sparks which causes the wire to rupture, 2developed a short circuit detecting system, which is performed by adjusting the chock inductance of the pulse generator and found that the unusual high rate of short circuit pulses during a period of 30 ms. or more proceeds wire rupture. The small pins were manufactured with use of WEDG process as shown in Fig. 1 which may be used as a tool for three dimensional electrical discharge machining (EDM) applications3.

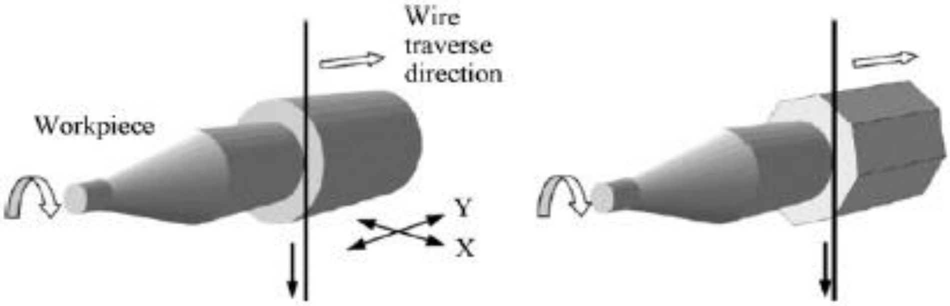

Fig.1 Concept of WEDG process[3]

The influence of various parameters like gap width, surface roughness and the depth of while layers in WEDM were studied and used Taguchi design technique to find the influence of the parameters[4].A multi objective optimization problem to get the optimal parameter combination in WEDM were formulated for MRR[5]. Micro-manufacturing technique has increasingly grabs research interest[6]. At present micro holes are formed by different manufacturing methods such as electron beam machining (EBM), micro-EDM, and electrochemical machining (ECM), laser machining and micro-ultrasonic machining (MUSM). Due to the different working mechanisms, these methods yield different results. Among them, micro-EDM provide merits such as low-cost apparatus, high aspect ratio of parts, and possesses capability of producing complex 3D shapes. It is therefore potentially suitable for manufacturing micro-holes and micro-parts in miniature devices[7]. In addition, EDM does not make direct contact between the electrode and work piece, thus eliminating chatter, mechanical stress and vibration problems during machining. EDM is a reliable non-conventional machining technique to carry out micro hole drilling in various materials[8,9] discussed the results of electrode wear and hole enlargement both are smaller when positive polarity is selected. Research focusing on influence of EDM parameters on material removal rate and electrode wear rate of martensitic stainless steel AISI 431[10]. Taguchi has proposed a method by acquiring the relevant data and with the use of orthogonal arrays, and to analyze the performance measures from the data in order to obtain the optimal process parameters[11]. The variation of cutting speed and surface roughness with cutting parameters were modeled by using regression analysis method[12].

Wire electrical discharge grinding with rotating workpiece is characterized by limited mechanical and thermal stability as well as by limited variable diameter of the work piece. Therefore by lowering the discharge energy a better surface can be attainable and also WEDG allows higher geometrical flexibility and electrode wear independent than the other process variants with rotating electrodes. The reachable removal rate is reduced by limitation of the discharge energy. At the same time the volume to remove per time unit increases due to the rotation of workpiece. Furthermore, the workpiece run-out error may cause periodical changing gap widths and the process behavior is substantially affected by the reduced active surface area between the electrode and work piece. The process of WEDG was studied for producing thin rods using travelling wire as a tool electrode[13]. This method exhibits high accuracy and repeatability with error less than 1µm. The ultimate goal of WEDM is optimizing the process parameters analytically with the elimination of the wire breakages and to improve the overall machining reliability[14]. Turning by WEDM was investigated to evaluate the effect of machining parameters on surface roughness and roundness based on Taguchi's Design of Experiments[15]. A rotary accessory was designed and fabricated in order to do an experimental study on wire electrical discharge grinding for hard and tough to machine materials[16]. The effect of surface roughness and roundness error using pulse train data acquired at the spark gap was discussed[17]. The recast layer and heat affected zone (HAZ) with surface roughness and MRR was investigated by[18]. The selection of cutting and offset parameters to get a desired Ra for a constant wire and dielectric flushing pressure was studied[19]. The micro machining of tungsten rods for the optimal parameters to get better diametric accuracy was analyzed[20]. The investigation by[21,22]in order to combine ultrasonic vibration with wire electric discharge turning to find out the influence of power, pulse off time and spindle rotational speed, ultrasonic vibration over MRR. The research of developing mathematical model for metal removal rate of the cylindrical wire EDM process is done[23]. An experimental study on machining of micro hole with high aspect ratio in difficult to machine alloys for aerospace industries was made and they developed a model to manufacture of micro electrodes[24]. WEDM corner cutting accuracy to obtain outside corners with a small corner angle and small thickness produces a machining error shaped like post-yield bending was investigated[25]. Our aim is to manufacture micro electrodes for Electric Discharge Machining by using Wire Electric Discharge Grinding Process which further can be used as a tool for machine micro holes on various materials. With the use of same process many of micro parts with complex shapes can be manufactured by the use of this method.

II. Selection Of Workpiece Materials

As concerned with the study of tool materials, EDM electrodes[2,5] need to have properties that allow charge and to resist the erosion that the EDM process encourages and stimulates in the metals it machines. The selected materials for electrodes are

- Brass
- Copper

Brass

The cylindrical brass rods are selected as one of the electrode material for the experimentation in EDM. The rods of Ø3.0mm shown in Fig. 2 were purchased with standard specification as ASTM per B927.

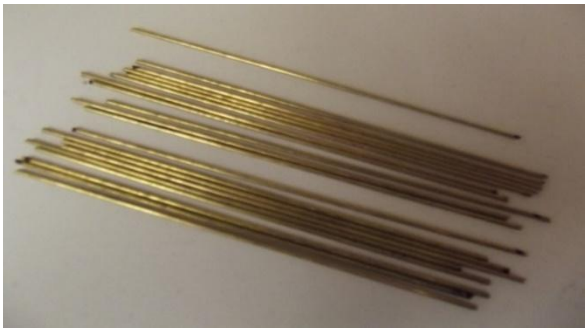

Fig. 2 Brass rods – Ø3.0mm

Copper

The cylindrical copper rods of Ø3mm shown in Fig. 3 with standard specification as per ASTM B187 purchased.

Fig. 3 Copper rods – Ø3mm

III. Fabrication Of Brass And Copper Electrodes

Machining in WEDG

The brass and copper rods are made as micro electrodes[2,3] which are to be used in EDM process. The size of rods is to be reduced by WEDG process shown in Fig 4. The rods are machined to obtain diameter less than Ø0.5mm. Electrodes of lesser diameter are to be used in micro hole drilling on hard materials.

Fabrication Process of Electrodes in WEDG

The experimental data for machining copper and brass electrodes is given in Table no 1.

Table no 1: Experimental data

Material to be machined	Brass and Copper
Size to be machined	Ø0.4mm(for 10mm length)
Machine used	Mitsubushi(FA106S) CNC WEDM
Supportive setup	Rotary axis setup

The process constants for machining the electrodes has been chosen automatically by the machine and given in Table no 2 and the parameters which we chose to vary are discussed separately.

Table no 2: Process constants

S. No.	Parameter	Value
1	Initial diameter of the specimen (mm)	Ø3.0
2	Final diameter (mm)	Ø0.4
3	Machining length (mm)	10
4	Wire tension (N)	10
5	Feed rate (mm/min)	3
6	Number of passes	1

Machining Data

- Rotary axis setup is fixed in support with WEDM machine. It rotates at variable speed of 100 to 1000rpm with the use of variable frequency drive (VFD).
- Cylindrical brass and copper rods of Ø3mm are fixed in the collet of the rotary axis setup shown in Fig. 4.
- Brass wire of Ø0.25mm is used in WEDM for the machining to be done in brass and copper rods.
- The brass wire tends to move vertically which machines the rods fixed in rotary axis setup.

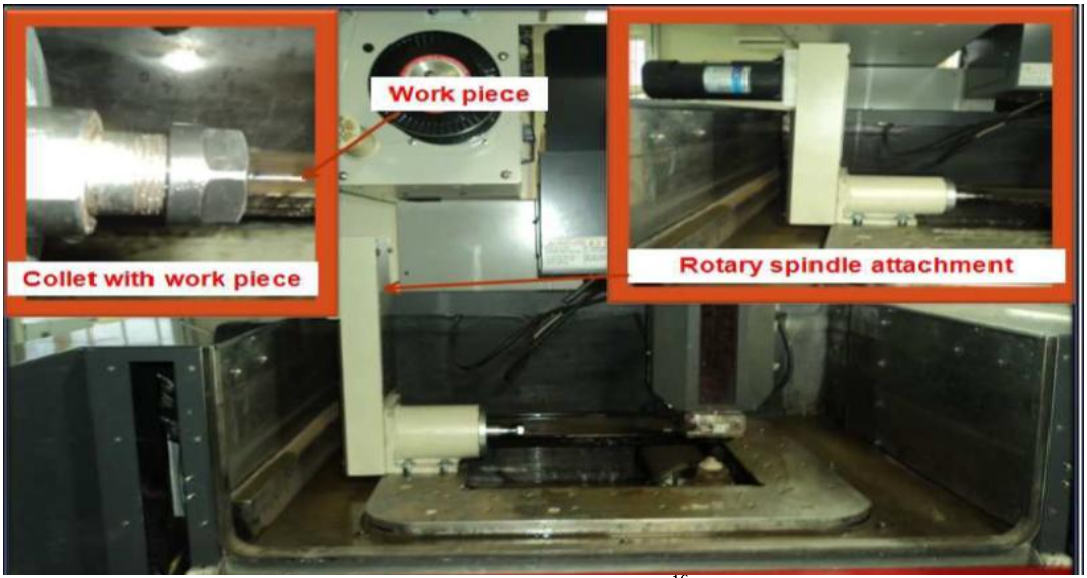

Fig. 4 Experimental Setup[16]

Parameters in WEDG

The machining parameters in WEDG are spindle speed, current, pulse offtime, wire speed. These parameters are set as default parameters for machining brass and copper electrodes for machining the brass and copper electrodes.

- Spindle speed
- Current
- Wire speed
- Pulse offtime

Levels of Parameters

The level of parameters are to be chosen for different set of machining operations has given in Table no 3. The parameters for machining Brass and Copper rods are same because of its ductile property. The density of the material are also almost equal so this paved the way for the same parameters to be selected. The feed rate and the other parameters as kept as per the process constants given by the machine.

Table no 3: Level of parameters

Parameters	Level 1	Level 2	Level 3
Spindle Speed (rpm)	100	150	250
Peak Current (A)	3	5	6
Pulse off time (μs)	4	3	1
Wire speed (m/min)	7	6	4

Fabricated Electrodes

The electrodes were fabricated with preferable machining methods and with the selected machining parameters.The fabricated brass and copper microelectrodes are shown in Figures5 and 6 respectively.

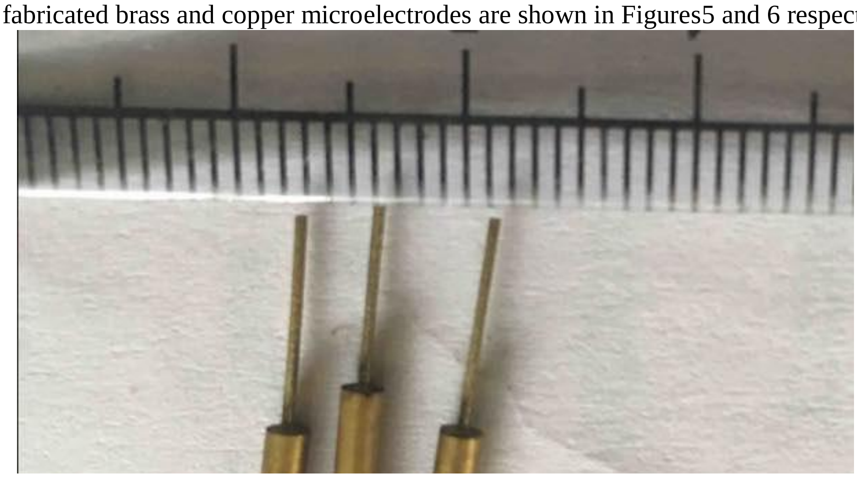

Fig. 5 Machined Brass Electrodes

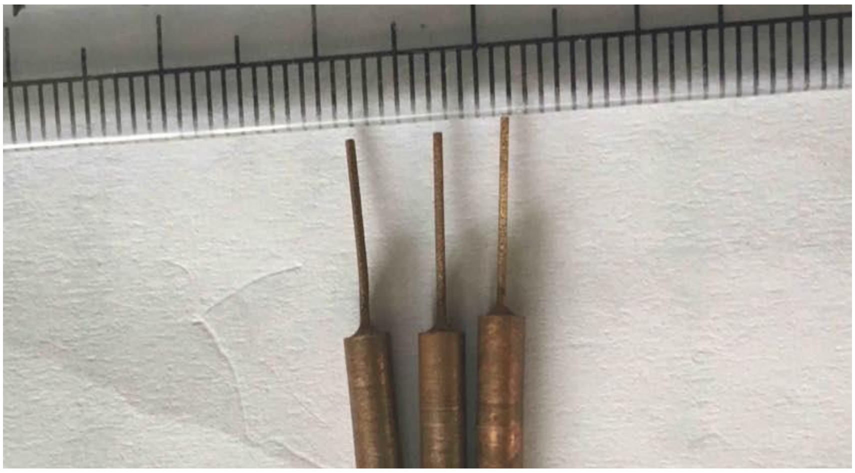

Fig. 6 Machined Copper Electrodes

Measurement of Microelectrodes

The measurement of micro electrodes are carried over in microscopy and its dimensions are measured for all the pieces. A sample measurement is shown in Fig. 7.

Fig. 7 Measurement of micro electrodes

Parameter selection for WEDG

By using full array L_{27} the design of experiments has been done and for the same signal to noise ratio graph was drawn in order to find the effect of each parameter. Table no 4 gives the array of parameters for design of experiments.

Table no 4: DOE array of parameters

S. No.	Spindle speed (rpm)	Peak current (A)	Pulse off time (μs)	Wire speed (m/min)
1	100	3	4	7
2	100	3	4	7
3	100	3	4	7
4	100	5	3	6
5	100	5	3	6
6	100	5	3	6
7	100	6	1	4
8	100	6	1	4
9	100	6	1	4
10	150	3	4	7
11	150	3	4	7
12	150	3	4	7
13	150	5	3	6
14	150	5	3	6
15	150	5	3	6

16	150	6	1	4
17	150	6	1	4
18	150	6	1	4
19	250	3	4	7
20	250	3	4	7
21	250	3	4	7
22	250	5	3	6
23	250	5	3	6
24	250	5	3	6
25	250	6	1	4
26	250	6	1	4
27	250	6	1	4

The machining parameters are selected based on the attainment of final diamter of rods and combination of DOE array. The appropriate diameter is obtained for a particular set of parameters are given in Table no 5.

Table no 5: Response on final diameter

S. No.	Initial Dia. (mm)	Final Dia. (mm) Brass	Final Dia. (mm) Copper
1	3.0	0.392	0.452
2	3.0	0.413	0.407
3	3.0	0.401	0.429
4	3.0	0.424	0.431
5	3.0	0.447	0.442
6	3.0	0.419	0.416
7	3.0	0.407	0.413
8	3.0	0.452	0.424
9	3.0	0.397	0.392
10	3.0	0.429	0.419
11	3.0	0.431	0.407
12	3.0	0.442	0.452
13	3.0	0.372	0.429
14	3.0	0.392	0.442
15	3.0	0.405	0.404
16	3.0	0.384	0.384
17	3.0	0.421	0.372
18	3.0	0.392	0.482
19	3.0	0.403	0.381
20	3.0	0.426	0.402
21	3.0	0.456	0.426
22	3.0	0.472	0.409
23	3.0	0.409	0.419
24	3.0	0.402	0.397
25	3.0	0.452	0.472
26	3.0	0.482	0.421
27	3.0	0.381	0.437

IV. Data Analysis On S/N Ratios

Brass

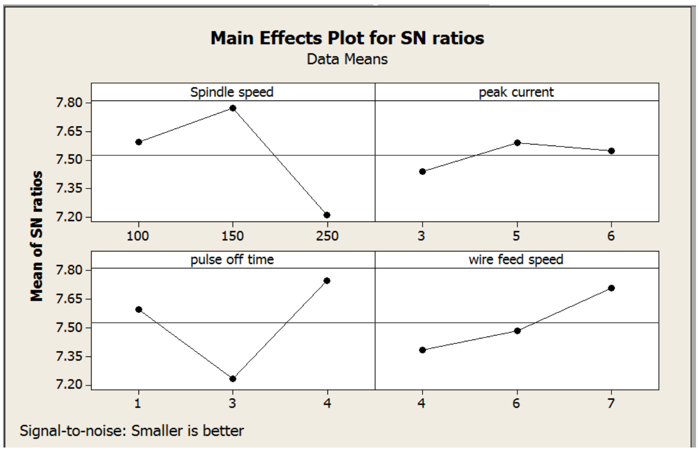

Fig.8 Main effect plots of S/N ratio for diameter

The smaller the better has been chosen and it is found to be spindle speed 250 rpm, peak current 3 A, pulse off time 3µs and with the wire speed of 4 m/min which has been found from the Fig.8 for machining brass. As brass being softer material more spindle speed leads to steep increase in material removal which leads to less accuracy of diameter while machining. Being softer when the input current is high which leads to variation in diameter. The less wire speed gives out proper thermal energy in conjunction with pulse of time of 3µs in order to achieve a better diameter.

Copper

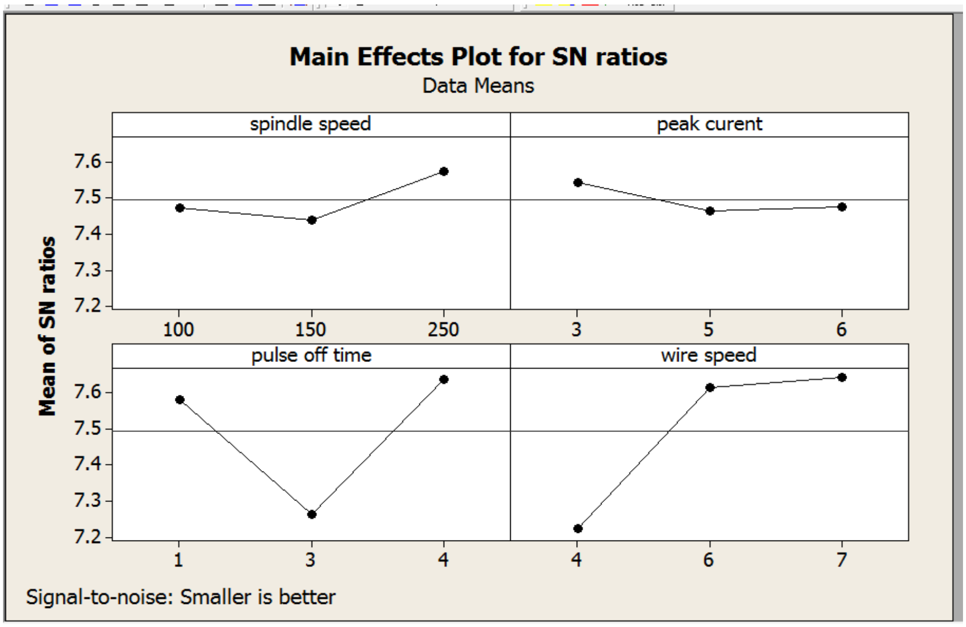

Fig. 9 Main effect plots of S/N ratio for Diameter

Optimal Parameters for Machining

Both brass and copper electrodes, were machined from Ø3.0mm to Ø0.40mm. The machining is carried out at a particular rate of time with the lowest material removal rate due to the material properties of brass and copper. The optimal parameters for machining copper and brass have given in the Table no 6 as per the S/N ratio analysis for the better diameter.

Table no 6: Optimal parameters

Parameters / Material	Spindle speed (rpm)	Peak current (A)	Pulse off time (µs)	Wire speed (m/min)	Final diameter (mm)
Brass	150	3	3	4	0.403
Copper	250	5	3	4	0.404

V. Conclusion

This paper depicts the manufacturing of micro electrodes by WEDG process. As the process is feasible in practice, the copper and brass electrodes of Ø0.40 mm are manufactured by this technique. WEDG process utilizes the selected set of parameters to obtain optimized machining of the materials. These manufactured electrodes can be used for micro drilling of hard materials through any EDM process. By using the same process, it is possible to make micro parts in any hard materials like HSS, Carbide, Tungsten, etc. as per the needs of the industrial applications. More spindle speed is not suitable for brass as the speed goes up which causes more material removal rate because of the softness compared to copper. The relationship between the pulse off time and wire speed is same for both the materials. Being copper is harder than brass it can able to withstand more current.

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