Analysis of Electro Chemical Micro Machining Process Parameters by Taguchi Orthogonal Array

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Abstract: The advancement of Mechanical engineering field is very essential to meet the growing demands of the industry. In particular the demand for alloy material having high hardness, toughness and impact resistance has grown multifold due to high level of design constraints. Electro Chemical Micro Machining (ECMM) process is well suited for marching any grade of hardness materials which are very difficult or else impossible for machining with conventional process. In addition, this machining process is specializing for machining complex shape jobs. And moreover, through this method of technique the tool need not be harder than work piece. Beryllium copper is taken as work piece because of its good electrical conductivity and copper is taken as tool for machining process. A mixture of water with Sodium Chloride is taken as electrolyte. The objective is to analyze three ECMM process parameter methods of voltage (V), of electrolyte concentration (gm/l) as well as rate of feed (µm/s) and to determine the MRR and surface finish of the material during the machining process. Then it's optimized using grey relation analysis method.

Keywords: ECMM, Beryllium copper, copper tool, water with sodium chloride electrolyte, optimized using grey relation analysis method.

I. INTRODUCTION

ECM is one of the advanced nontraditional techniques for manufacturing which is utilized for machining alloy material which have high hardness and high ductility. ECM work on the principal of Michael Faraday law. When ECM is performed at micro meter level (range of MRR from 1-999 µm), that is called Electro Chemical Micro Machining (ECMM). It could be used in favor of making smaller size components with high precision. The high precision components with holes in micro size, various types of slots along with multifaceted surfaces which having largely wanted for mission critical applications like Nuclear power plant, Aero space industry, Electronics industry, and Bio-medical field. . ECMM is a very promising technology since several advantages are offering for examples superior rate of machining, betterment of precision as well as control, machining materials with extensive range, cost effective, and environmental friendly The ECMM process is capable of machining electrically conductive, hard to cut materials without introducing any deformation on machined surface. In this process, no tool wear is produced. Further, no residual stress is caused because machining is not done with direct force on the work piece. Instead, ionic dissolution is used to remove the material. Hence, there is no heat generation involved while machining. The ECMM process could be utilized effectively intended for the operation required for more precision machining with micro burrs and producing patterns for foils as well as three dimensional micromachining. Beryllium copper is an aged hardened alloy having developed higher strengths and it has non corrosive and abrasive wear resistant find wide application in aerospace automotive and other industrial.

Bhattacharyya et al (2007) stated that the rate of material removal could be resoluted through the density of the applied current along with tool and workpiece distance [1]. Kuppan et al (2008) found that the chemical energy is one of the main factors that consider removal of material from the work piece in ECMM. [2]. Jailani et al (2009) suggested that the best possible parameter value could be determined through the maximum level of the average grey relational. [3].

Somashekhar et al (2010) showed the level of majority influencing showed maximum-minimum along with parameters of inputs could determine characteristics of machining [4]. Muthuramalingama et al (2013) investigated that the process of the machining it is found that ideal sequence is one of the most excellent response. The indication of higher grey grade in the place is nearer the process optimal response [5]. Sudiarso et al (2013) applied the voltage, concentration of electrolyte, federate of micro tool and duty cycle are taken input parameters in ECMM process [6].

Muthuramalingama et al (2014) found that while considering highest rate of material removal would be selected the superior quality characteristics. [7]. Muthuramalingama et al (2015) stated that the number of problems would be arising like higher rough of the workpiece surface, zone affection by heat, and stress due to thermal when machining hardened materials using traditional machining process [8]. Teimouri et al (2015) created the permutation of artificial bee colony algorithm as well as fuzzy logic could be used for creating the map for prediction in forward through input parameters in cause of

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stir welding with the power of friction[9]. Lu et al (2016) studied the micro milling with Inconel78 for prediction the rough of the machined surface [10]. Panv et al (2016) found that the conventional machining process causes for introducing residual stresses into the Job materials and undesirable properties of materials [11].

The objective of our research work is o analyze three ECMM method of process machining parameters of voltage (V), electrode concentration (gm/l) as well as the rate of feed (µm/s) and to determine the MRR and surface finish of the material during the machining process. Then it's optimized using grey relation analysis method.

II. METHODOLOGY

The main aim our research is studying parameters involving and their influence in ECMM such as electrolyte concentration, machining voltage, feed rate on material removal rate on Beryllium copper. Further, design of experiments employing Taguchi's Technique, are used to find the best suited experiments by the process parameters. ECMM parameters like MRR and important role in modeling the machining parameters for achieving the selected objectives. This research mainly concentrates in finding ECMM process parameters to achieve MRR in beryllium copper C17200.

Statement of the Problem

Investigation made of machining on the material of beryllium copper C17200 using ECMM process. This research mainly concentrates in finding ECMM process parameters to achieve material removal rate in workpiece. The parameters subjected to the study are machining voltage, electrolyte concentration and feed rate. In this study, Taguchi methodology is used to determine the design of experiments and Grey Relation optimization technique is used to determine which level of respective parameter is suitable for machining process.

III. EXPERIMENTAL SETUP

The ECMM system developed to conduct experiments for this research work has the following five major assemblies. The entire experimentation has been performed through the set-up of Electrochemical Machining with input of the power supply of 415 v + or - 10%; three phase AC, 50 HZ 0-300A DC is the output supply at all voltage from 0-25V along with efficiency is improved than 80% by partial as well as condition of full load. The insulation resistance of the cable should not less than 10 Mega ohms among 500V DC. Figure 1 shows the set-up of experimentation.

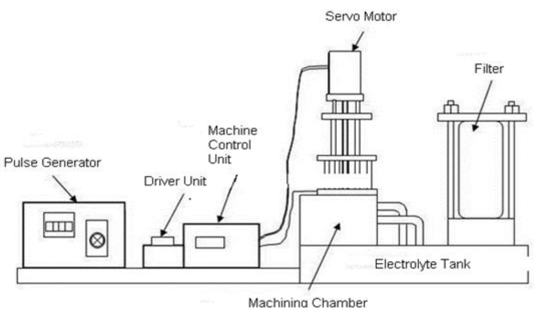

Fig. 1 Experimentation set-up

Experimental details

When the stepper motor rotates, the lead screw rotates and which in turn moves the micro tool electrode holding device which provides electrode feed movements.

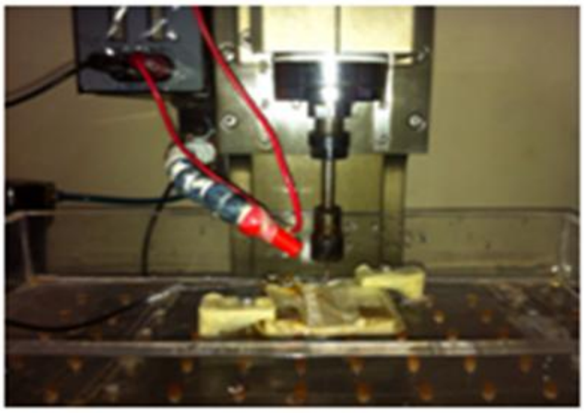

Fig. 2 Work Holding Platform and Tool holding Arrangement

Just below the tool electrode holding devices, the machining chamber rests on a base plate. The base plate is provided with four bushes at the bottom for easy handling Beryllium copper C17200 is selected as work piece. The dimension of the work piece is 50×20×0.3mm. A copper rod of 0.8mm diameter is selected as tool for machining process and the mixture of water and sodium chloride is taken as electrolyte for the machining process. The work holding platform and tool holding Arrangement is shown in Figure 2.

The material details and composition are tabulated in Table 1 and Table 2,

Table. 1 Material details

Details	Date
Category	Beryllium copper
Class	RWMA class IV
Type	D1710 type 1
Designations	European standard CuBe2, DIN2.1247,CW101C to EN

Table. 2 Material compositions

SPEC. FOR ASTM B194 UNS NO C17200			Actual values
	Min.	Max.	
Beryllium	1.80%	2.00%	1.934%
Aluminium	-	0.20%	0.012%
Silicon	-	0.20%	0.030%
Nickel + Cobalt	-	0.20%	0.139%
Nickel + Cobalt + Iron	-	0.60%	0.243%
Copper	REMAINDER		97.62%

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Mechanical and Thermal Properties of the work piece are density 8.36(g/cm^3), Elastic modulus13.40 (Kg/mm^2) and Thermal Expansion Coefficient ($20^{\circ}C$ to $200^{\circ}C$) 17×10^{-6} m/m/$^{\circ}$C.

IV. TAGUCHI EXPERIMENTAL DESIGN AND ANALYSIS

Taguchi recommend orthogonal array (OA) is following with respect of experimental work. OA's has been widespread Graeco Latin squares. The design of experiment has been selected for very suitable of OA in addition to allocate the parameters along with interaction of significance to the suitable column. Apply of graph for linear with triangular form of table recommended by taguchi's creates assignment parameters very easy. The array forces of every experimenters for designing nearly equal experiments.

Selection of Orthogonal Array

In order to identify the true behavior of Material Removal Rate (MRR) three process parameters everyone at the level of three has considered for this study as tabulated in Table 3 and 4.

Table. 3 Levels and factors of parameter in the experimental

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
Voltage (V)	18	20	22
Concentration (gm/l)	20	25	30
Rate of Feed (µm/s)	0.8	0.9	1

The three process parameters for example electrolyte concentration; machining voltage as well as feed rate are studied by Taguchi method using L_9 Orthogonal Array as shown in table 4 and its optimized using grey relation analysis.

Table. 4 Value Levels of experimental parameters

Exp. No	Levels of process parameters		
	Voltage (v)	**Electrolyte Concentration (gm/Lit)**	**Feed Rate (µm/s)**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Experimental Procedure

1. The setup is first cleaned
2. The fixture is then placed in the glass tank which is used for the flow and temporary storage of the electrolyte
3. Then the tool is fixed in the tool holding device.
4. The tool used here is a copper rod of 0.8mm diameter.
5. Then the Sodium Chloride is mixed with water to form appropriate mixture which is used as Electrolyte for the machining process
6. The temperature of the electrolyte is same as of the room temperature
7. Then the mixture is put in electrolyte storage tank
8. Then the work piece i.e. Beryllium chloride of size 50*20*0.3 mm is placed on the fixture.
9. The nozzle from which the electrolyte is sprayed is kept facing the area of the work piece where the machining should take place.
10. The work piece has been connected with positive terminal and thus workpiece acts as anode.
11. The tool has connected with negative terminal and thus tool acts as cathode.
12. Then the tool has placed near work piece with gap of 0.1mm.
13. Then the readings are given as per the design of experiments which has been derived using taguchi method
14. A system with HYPERMESH2 software is used vary the process parameters.
15. This procedure is done for all the 9 experiments in the L9 orthogonal array.
16. After machining process the MRR is calculated and the surface roughness is tested for all the 9 experiments.
17. Then Grey Relation analysis is done in order to optimize the parameters.
18. Then ANOVA table is put to determine the effect of process parameters.

ANOVA (Analysis Of Variance)

1. First enter the values in the corresponding columns i.e. C1 for experiment number , C2 for Voltage , C3 for electrolyte concentration , C4 for feed rate, C5 for MRR and C6 for Surface Roughness.
2. Then click on 'Stat' tab
3. Select 'ANOVA' in the 'Stat' tab drop down list
4. Then from 'ANOVA' drop down list select 'General Linear Model'
5. A new window of 'General Linear Model' appears.
6. In that window select MRR as Responses and voltage, electrolyte concentration and feed rate in the model box.
7. Then click 'OK'
8. The ANOVA values are calculated and Displayed in the 'session' box.
9. Similarly the ANOVA for Surface Roughness is also found out.

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10. Thus this is how ANOVA is calculated using MINITAB software and the found out values are discussed below.

Steps for Optimization

1. Classification of performance characteristics along with process parameters have evaluated.
2. Decision for the levels of parameters in process.
3. Choose suitable orthogonal array then allocate process parameters for orthogonal array.
4. Carry out trial arrangement of the array of orthogonal.
5. Normalize outcome results from experiments regarding response parameters of MRR as well as roughness of the surface.
6. Execute generating of grey relational in addition to work out the coefficient of grey relational.
7. Compute grade of the grey relational through averaging coefficient of grey relational.
8. Evaluate experimentation results by utilizing grade of grey relational along with statistical analysis of variance,
9. Choose process parameters in optimal level.
10. Validate best process of parameters by confirmation experiment.

Experimentation

When the investigation of grey relational, the pre-processing of data is primarily performed with the aim of normalize raw data for analyzing. In our research work, a linear normalization of experimental outcome of MRR as well as the roughness of surface is done with range in zero to one and is also indicate the grey relational generation. There are three various kinds of results through normalizing and written as:

i. Lower the better

$$x^*_i(k) = \frac{\max x_i^{(0)}(k) - x_i^{(0)}(k)}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)}$$

ii. Higher the better

$$x^*_i(k) = \frac{x_i^{(0)}(k) - \min x_i^{(0)}(k)}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)}$$

iii. A desired value

$$x^*_i(k) = 1 - \frac{\left|x_i^{(0)}(k) - x^{(0)}\right|}{\max x_i^{(0)}(k) - x^{(0)}}$$

The grey relational coefficient could be written as:

$$\Gamma_{oi} = \frac{\Delta_{\min} + \Delta_{\max}}{\Delta' + \Delta_{\max}}$$

$$\Delta' = |\, 1 - \Delta_{oi} \,|$$

V. RESULTS AND DISCUSSIONS

Orthogonal Array

The graphs for surface roughness and the optimized values of process parameter i.e. experiment no.6 are compared. The Figure 3 indicates surface roughness on material prior to machining process.

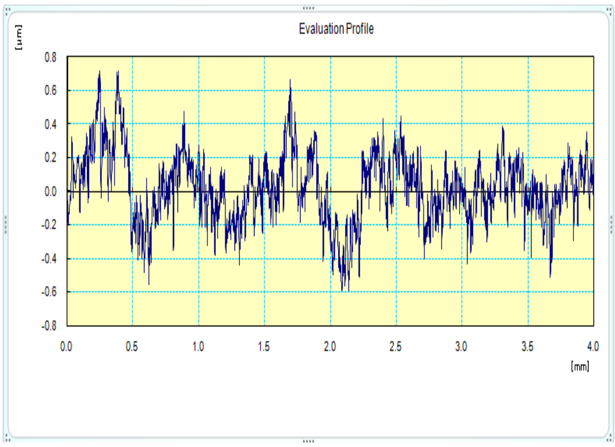

Fig. 3 Surface Roughness of the material before machining

The mmachined workpiece microstructure with the Magnification: 100X and its circumference of the machined zone are shown in Figure 4 and 5. The experimental results for MRR rate as well as the surface roughness are tabulated through Table 5.

Fig. 4 Machined workpiece microstructure with the Magnification: 100X

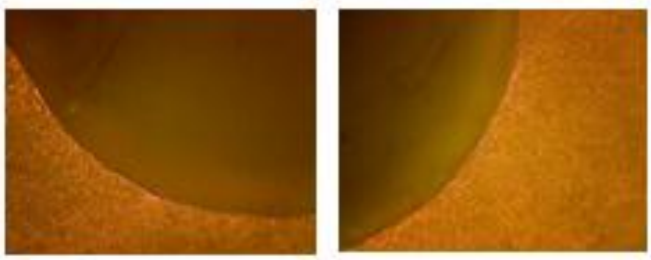

Fig. 5 Circumference of the machined zone

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Table. 5 The process levels in parameters of MRR as well as the surface roughness

Exp. No	Levels of process parameters		
	Voltage (v)	Electrolyte Concentration (gm/Lit)	Feed Rate (µm/s)
1	18	20	0.8
2	18	25	0.9
3	18	30	1
4	20	20	0.9
5	20	25	1
6	20	30	0.8
7	22	20	1
8	22	25	0.8
9	22	30	0.9

The microscopic for the workpiece which has been machined at process parameters is in experiment no.6 which has been proved as optimal level for machining with the help of grey relation analysis**.**

V. CONCLUSION

Beryllium copper C17200 Work piece with copper as tool and a mixture of Sodium Chloride and water as electrolyte. The MRR rate as well as surface roughness has been calculated under various process parameters. The Orthogonal array among grey relational investigation has been employed for optimizing characteristics of multi response.

The results that indicate that

- The best possible process parameters permutation for ECMM method are A2B3C1 (20V, 30gm/lit, 0.8 µm/s.) which corresponds to the parameters Machining Voltage; Electrolyte Concentration as well as rate of feed of Electro Chemical Micro Machining Process.
- From the ANOVA table 6.5 evident so as to, feed rate is a important factor, which affect MRR of Beryllium Copper metal.
- From the ANOVA table 6.6 it is evident that Electrolyte Concentration as well as Voltage are significant factors which affect the Surface Roughness of Beryllium Copper metal.
- The Grey relational investigation as well as Taguchi technique is a better tools for optimization of multi response Manufacturing problems.

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