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# Optimization Study of Electrochemical Machining Process

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**Abstract:** The objective of this research is to study the influence of Electro Chemical Micro Machining (ECMM) process parameters such as electrolyte concentration, machining voltage, feed rate on Material Removal rate of work piece -Beryllium copper. Further, designs of experiments employing Taguchi's Technique were used to find the best suited experiments by the process parameters. ECMM experiments were conducted on Beryllium copper C17200 work piece with copper as tool and a mixture of sodium chloride and water as electrolyte. The material removal rate (MRR) and surface roughness were calculated under various process parameters. Orthogonal array with grey relational analysis were employed to optimize the multi response characteristics.

**Key words:** Electro chemical micro machining**,** Taguchi method, process parameters, Design of experiments.

## 1. Introduction

Electrochemical machining technology was first recommended by Prof. Gussev in 1929 and it is a nontraditional manufacturing technique. The efficiency of products put a new demand for manufacturing technologies to react to these new necessities and Electrochemical micro-manufacturing technology (ECMM) is one of the most promising technologies [1]. ECM (Electrochemical Machining) are fated for the micro machining and a high process accuracy of the removal processes [2].

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.Also Beryllium–copper alloys possess high tensile and compressive strength, high hardness, good thermal conductivity [3]. Micro machining technology [4] enables machining of complex to machine shapes and surfaces, drilling of micro-holes, and other special requirements in electronic industries. These things are also performed by using conventional machining techniques, but the problems generally faced are a) tool wear, b) rigidity problem of the tool, and c) heat generation at the tool–work piece.

This research mainly concentratesin finding ECMM process parameters [5] to achieve MRR in beryllium copper C17200.The grey relational analysis utilizing Taguchi method was employed for optimizing respective parameter suitable for machining process [6].Beryllium copper C17200 [7] is selected as work piece. The dimension of the workpiece is 50*20*0.3mm .And 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.

## 2. Experiment

The whole experimental conducted on Electrochemical Machining set up which is having input Supply of 415 v +/- 10%, 3 phase AC, 50 HZ. Output supply is 0-300A DC at any voltage from 0-25V and efficiency is better than 80% at partial and full load condition. The cable insulation resistance is not less than 10 Mega ohms with 500V DC. The experimental setup is shown in figure1.

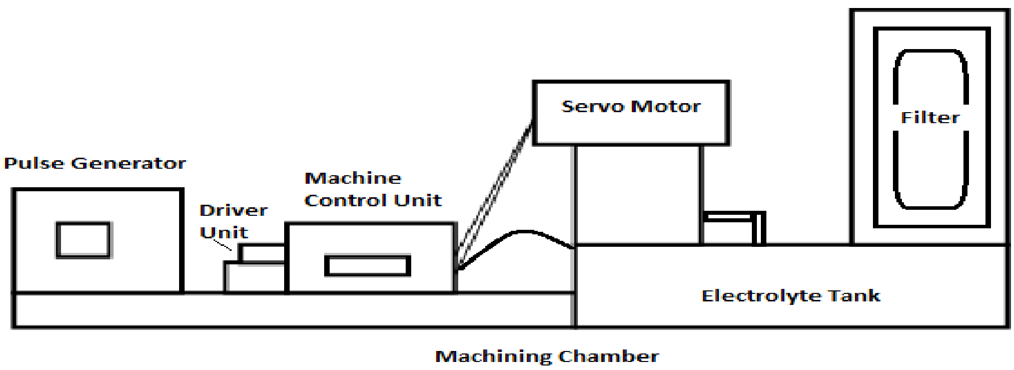


figure 1. schematic diagram of experimental setup

## 3. SpecificationofWork-Piece Material:

Experiment was conducted on C17200 Beryllium copper as a work-piece. The specification of the material is given in Table 1 and chemical composition in Table 2. The mechanical and thermal properties are presented in Table 3. Work-piece of dimension (50×20×0.3) mm and pieces of C17200 Beryllium copper were taken to conduct 9 experimental runs.

Table 1: Description of C17200 Beryllium copper

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

Table 2: Work piece Composition

| **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% |

Table 3: Mechanical and Thermal Properties

| **PARAMETERS** | **VALUES** |
|---|---|
| Density ($g/cm^3$) | 8.36 |
| Elastic modulus ($Kg/mm^2$) | 13.40 |
| Thermal Expansion Coefficient (20 ° C to 200°C m/m/°C | $17×10^{-6}$ |

## 4. Design of experiments.

In order to identify the true behavior of material removal rate , three process parameters each at three levels were considered for this study. The levels of the process parameter are given in table 4.

Table 4: Process Parameters and their Levels

| **FACTORS** | **LEVEL-1** | **LEVEL-2** | **LEVEL -3** |
|---|---|---|---|
| Voltage (V) | 18 | 20 | 22 |
| Electrolyte Concentration (gm/l) | 20 | 25 | 30 |
| Feed rate (µm/s) | 0.8 | 0.9 | 1 |

The three process parameters [8]. Electrolyte concentration, Machining voltage, feed rate were studied by Taguchi method using $L_9$ Orthogonal Array as shown in table 5 and it was optimized using grey relation analysis [11].

Table 5: Experiment Layout using $L_9$ Orthogonal Array

| **Exp. No** | **Levels of process parameters** | | |
|---|---|---|---|
| | **Voltage (v)** | **Electrolyte Concentration (gm/Lit)** | **Feed Rate (µm/s)** |
| E1 | 1 | 1 | 1 |
| E2 | 1 | 2 | 2 |
| E3 | 1 | 3 | 3 |
| E4 | 2 | 1 | 2 |
| E5 | 2 | 2 | 3 |
| E6 | 2 | 3 | 1 |
| E7 | 3 | 1 | 3 |
| E8 | 3 | 2 | 1 |
| E9 | 3 | 3 | 2 |

**4.1. Analysis of Variance(ANOVA)**

ANOVA is a statistically based, objective decision-making tool for finding any differences in the average performance of groups of items tested [9]. The Experimental layout of values of process parameters[12] in $L_9$ Orthogonal array and results of MRR and surface roughness,ANOVA for the machining outputsare presented in Table 6 and 7.

Table6. Experimental layout of values of process parameters in $L_9$Orthogonal array**.**

| **Exp. No** | **Levels of process parameters** | | |
|---|---|---|---|
| | **Voltage (v)** | **Electrolyte Concentration (gm/Lit)** | **Feed Rate (µm/s)** |
| E1 | 18 | 20 | 0.8 |
| E2 | 18 | 25 | 0.9 |
| E3 | 18 | 30 | 1 |
| E4 | 20 | 20 | 0.9 |
| E5 | 20 | 25 | 1 |
| E6 | 20 | 30 | 0.8 |
| E7 | 22 | 20 | 1 |
| E8 | 22 | 25 | 0.8 |
| E9 | 22 | 30 | 0.9 |

Table 7. Results of MRR and Surface Roughness

| **Exp . No** | **Levels of process parameters** | **Material Removal Rate MRR ($\mu m^3$/min)** | **Surface roughness (µm)** |
|---|---|---|---|

| | Voltage (v) | Electrolyte Concentration (gm/Lit) | Feed Rate (μm/s) | | |
|---|---|---|---|---|---|
| E1 | 18 | 20 | 0.8 | 1.67 | 0.678 |
| E2 | 18 | 25 | 0.9 | 2.35 | 0.694 |
| E3 | 18 | 30 | 1 | 3.125 | 0.711 |
| E4 | 20 | 20 | 0.9 | 5 | 0.684 |
| E5 | 20 | 25 | 1 | 7.5 | 0.703 |
| E6 | 20 | 30 | 0.8 | 6.52 | 0.673 |
| E7 | 22 | 20 | 1 | 4.44 | 0.709 |
| E8 | 22 | 25 | 0.8 | 5.71 | 0.684 |
| E9 | 22 | 30 | 0.9 | 5.26 | 0.689 |

## 5. Results and Discussion

**Grey Relation Analysis for ECMM**

The Grey relational grade and rank of each experiment were calculated from the given experiments and is shown in table 8.

And the average grey relational grade values for each level of the parameter were calculated, and tabulated inTable 9.

Under consideration the experiment No. 6 which has highest grade is the optimal parameter for machining process[10].

Table 8.Grey Relational coefficient and grey relational grade

| Exp. No | Material Removal Rate MRR (μm3/min) | Surface roughness (μm) | Grey Relation Grade | Rank |
|---|---|---|---|---|
| E1 | 1.67 | 0.678 | 0.69186 | 6 |
| E2 | 2.35 | 0.694 | 0.587517 | 7 |
| E3 | 3.125 | 0.711 | 0.535644 | 9 |
| E4 | 5 | 0.684 | 0.737695 | 4 |
| E5 | 7.5 | 0.703 | 0.779412 | 2 |
| E6 | 6.52 | 0.673 | 0.928047 | 1 |
| E7 | 4.44 | 0.709 | 0.584653 | 8 |
| E8 | 5.71 | 0.684 | 0.770301 | 3 |
| E9 | 5.26 | 0.689 | 0.713066 | 5 |

Table9. Average grey relation grade

| SOURCE | LEVEL1 | LEVEL2 | LEVEL3 |
|---|---|---|---|
| Voltage(A) | 0.605007 | **0.815051** | 0.68934 |
| Electrolyte Concentration(B) | 0.671403 | 0.71241 | **0.725586** |
| Feed Rate(C) | **0.796736** | 0.679426 | 0.633236 |

Thus from table from 9 level2 for voltage , level3 for electrolyte concentration and level1 for feed rate are optimal values for machining process in electrochemical micro machining process i.e. A2B3C1 combination is suited for good surface finish and metal removal rate.

MINITAB was used for ANOVA calculation and Table 10 gives ANOVA values for MRR vs. the 3 parameters and table 11 gives the ANOVA values for Surface Roughness vs. the 3 parameters.

Table 10. MRR versus voltage, electrolyte concentration and feed rate

| Source | Degree of Freedom | Sum of Squares | Mean Square | F Value | P |
|---|---|---|---|---|---|
| Voltage | 2 | 24.7064 | 12.3532 | 118.02 | 0.008 |
| Electrolyte Concentration | 2 | 3.8482 | 1.9241 | 18.38 | 0.052 |
| Feed rate | 2 | 1.0054 | 0.5027 | 4.80 | 0.172 |
| Error | 2 | 0.2093 | 0.1047 | | |
| Total | 8 | 29.7693 | | | |

Table11. Surface roughness versus voltage, electrolyte concentration and feed rate

| Source | Degree of Freedom | Sum of Squares | Mean Square | F Value | P |
|---|---|---|---|---|---|
| Voltage | 2 | 0.0001127 | 0.0000563 | 8.05 | 0.111 |
| Electrolyte Concentration | 2 | 0.0000187 | 0.0000093 | 1.33 | 0.429 |
| Feed rate | 2 | 0.0013227 | 0.0006613 | 94.48 | 0.010 |
| Error | 2 | 0.0000140 | 0.0000070 | | |
| Total | 8 | 0.0014680 | | | |

**5.1. Surface Roughness**

The graphs for surface roughness and the optimized values of process parameter i.e. experiment no.6 (E6) were compared and shown in Fig2 and it shows the surface roughness of the material before machining process and graph 3.represents the surface roughness of the material after machining at optimal levels of the three selected parameters.

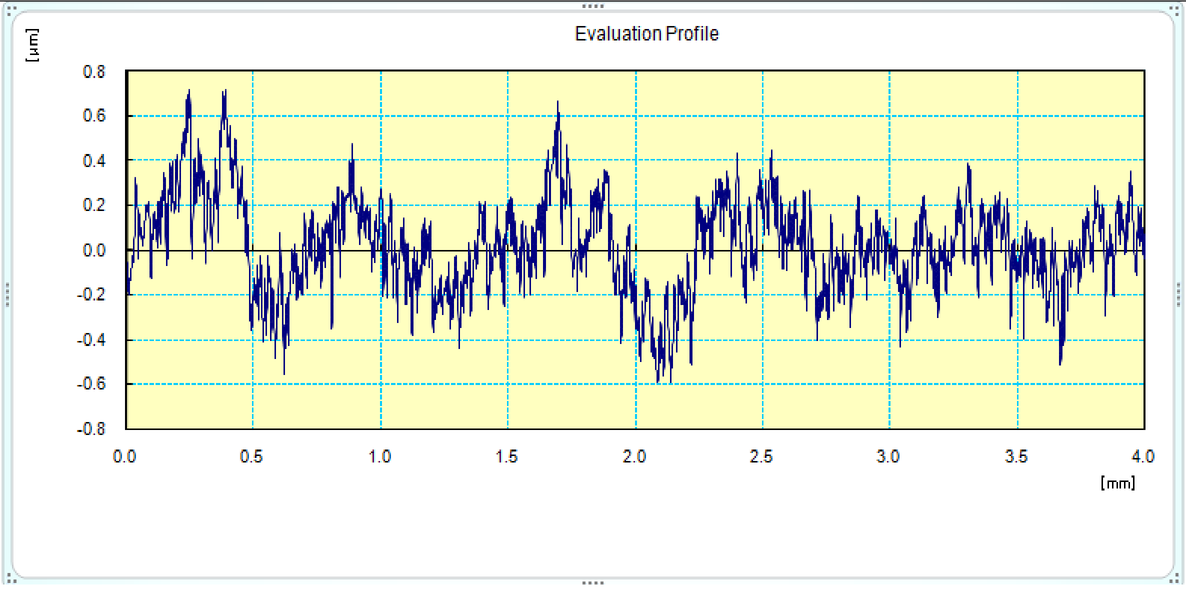


figure 2.surface roughness of the material before machining

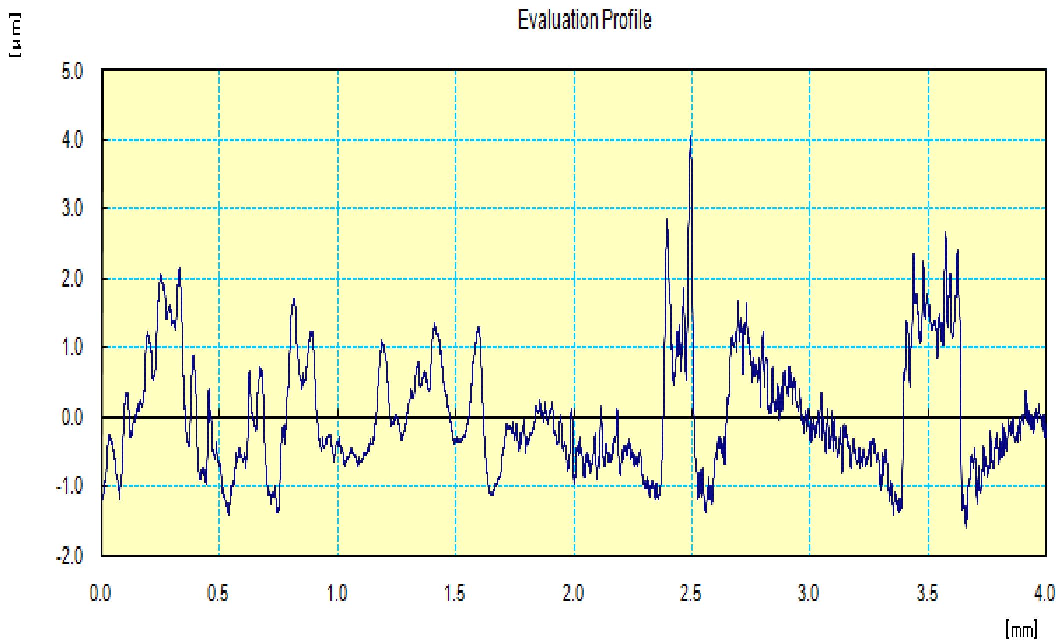


figure 3. surface roughness of the material after machining at optimum levels of process parameters

## 6. Conclusion

- The Electro chemicalMicro Machining (ECMM) experiments were conducted on Beryllium copper C17200 Work piece with copper as tool and a mixture of Sodium Chloride and water as electrolyte. The material removal rate and surface roughness were calculated under various process parameters. Orthogonal array with grey relational analysis was employed to optimize the multi response characteristics.
- The results that indicate that the optimal process parameters combination for ECMM process are A2B3C1(20V , 30gm/lit , 0.8 µm/s.) which corresponds to the parameters Machining Voltage , Electrolyte Concentration and feed rate of the ECMM Process.
- From the ANOVA table 10, it is evident that, feed rate is a significant factor, which affects theMaterial removal rate of Beryllium Copper metal.

- From the ANOVA table 11, it is evident that Electrolyte Concentration and Voltage are significant factors which affect the Surface Roughness of Beryllium Copper metal.
- Thus the Grey relational analysis and Taguchi method are useful tools for the optimization of multi response problems.

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