# Optimizing the Overcut Parameter of Micro-Holes Machining by EDM Using Taguchi Method

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**Received on: 13/12/2012 & Accepted on: 4/7/2013**

## ABSTRACT

In this paper Taguchi method was performed to estimate the optimum overcut parameter for Electro Discharge Machining (EDM) to obtain micro-holes of copper alloy workpieces. Taguchi method is used to formulate the experimental layout, to analyses the effect of each parameter on the machining characteristics and to predict the optimal choice for each machining parameter (current, gap distance and machining time), and analyzed the effect of these parameters on the overcut parameter. The analysis shows that, the current significantly affects the overcut parameter.

**Keywords:** EDM, Micro-Holes, Taguchi Method

# إيجاد عامل تجاوز القطع المثالي في التشغيل بالشرارة الكهربائية للثقوب الدقيقة باستخدام طريقة Taguchi

## الخلاصة

في هذه المقالة تم استخدام طريقة تاجاشي لتقدير القيمة المثلى لعامل تجاوز القطع للتشغيل بالشرارة الكهربائية للحصول على ثقوب دقيقة لعينات من سبيكة النحاس. استخدمت طريقة تاجاشي لصياغة النموذج التجريبي وتحليل تأثير كل متغير على الخصائص التشغيلية والتنبؤ بأمثل اختيار لكل متغير تشغيلي (التيار ، مسافة الفجوة وزمن التشغيل)، وتحليل تأثير كل متغير من هذه المتغيرات على عامل تجاوز القطع. اظهر التحليل ان التيار هو المؤثر الفعال على عامل تجاوز القطع.

## INTRODUCTION

EDM is a non-conventional manufacturing process. In this process, the material is removed by erosive action of electric discharges occurring between a tool electrode and work piece based on the fact that no tool force is generated during machining. Both work piece and tool electrode are submerged in a solution called dielectric. The mechanical characteristics of work piece and electrode are nota concern because the electrical energy is converted into thermal energy causing melting of the material. EDM process allows the machining of hard materials and more complex shapes which cannot be processed by other conventional methods. The EDM process is normally applied to mould and die making. Compared to conventional machining method, the material removal rate of this machining remains rather low [1, 2].Electro Discharge EDM is a process of removing material in a closely controlled manner from anelectrically conductive material immersed in a liquid dielectric by a series of randomly distributed discrete electrical sparks or discharges. Non-conducting materials cannot actdirectly on electro detoachieve EDM. In order to machine these materials with EDM, the conditions that electrical discharges can be produced on their surface must be created [3].

Machining (EDM) has a wide variety of applications in industry for material removal processes. EDM have the ability to produce micro-holes with a good dimensional quality. To produce a precise micro-hole, the overcut parameter should be optimized. The overcut parameter is highly affecting machining performance. It can calculate by subtracting the Diameter of machined micro-hole from the Diameter of electrode tool [4].

In this paper, Taguchi $L_9$ orthogonal array is employed to analyze experimental results of using EDM process to produce micro-holes in copper alloy specimens from nine experiments by varying three process parameters (current, gap distance, machining time).

## EXPERIMENTAL PART

In this work, copper alloy is used. Table (1), shows the material properties. The experiments were accomplished using EDM system which is designed for this work. Figure (1) shows schematically the experimental setup for the machining process and Figure (2) shows EDM system.

Machining experiments carried out by using DC current and 70 V voltage to cut 0.7 mm thickness of copper alloy work pieces, using stainless steel electrodes and dielectric solution (tap water).

## PLAN OF EXPERIMENTS

The experimental layout was developed based on Taguchi's orthogonal array experimentation technique. An $L_9$ orthogonal array experimental layout was selected to satisfy the minimum number of experiment conditions for the factors and levels. This array having three control parameters and three levels, as shown in Table (2).

A series of machining tests are conducted to assess the effect of machining parameters on the overcut. Experimental results are shown in Table (3).

## DATA ANALYSIS

In this work, analysis based on the Taguchi method is performed by utilizing the Minitab software to estimate the significant factors of the EDM process parameters and graphical analysis of the obtained data.

Taguchi's orthogonal array is highly functional design, used to estimate main effects using few experimental tests only.

These designs can investigate main effects when factors have more than two levels. In Taguchi method, the analysis of variation is performed using Signal – to – Noise ratio (S/N). There are three S/N ratio approaches of common interest for optimization.

They are as follows:

1. Smaller – the better (for making the system response as small as possible).
2. Larger – the better (for making the system response as large as possible).
3. Nominal – the best (for reducing variability around the target).

In this work, the objective is to minimize the overcut parameter to produce micro-holes with high dimensional accuracy. Therefore, the S/N ratio for each experiment of $L_9$ calculated using smaller the better approach. The objective of using S/N ratio as a performance measurement is to develop a product and process insensitive to noise factor. In Taguchi method, the term “signal” represents the desirable value (mean) for the output characteristic, and the term “noise” represents the undesirable value (square deviation) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to square deviation. S/N ratio of the overcut is calculated by:

$$\frac{S}{N} = -10\log\left(\frac{(\sum Y_i)^2}{n}\right)$$

Where: $Y_i$: is the ith observed value of the response.

n: number of observations.

S/N ratio is used to measure the quality characteristic deviating from the desired value. Steps applied in Taguchi method are summarized in Figure (2).

Figure (3) shows the main effects of overcut of each factor for various level conditions. According to this figure, the overcut decreases with high level of current and low level of machining time.

The analysis of S/N ratio of overcut parameter with small – the better approach shown in Figure (4), revealed that the smallest value of overcut is achieved at current of (4A), Gap distance of (0.4mm), and machining time of (10min).

## RESULTS AND DISCUSSION

Overcut parameter is one of the main design functions in EDM processes. It plays the major role to optimize the process of producing micro-holes using EDM. According to the ranks of the slop of S/N ratios plot, shown in Table. 4, that affect of various input factors on overcut in sequence of its effect are: Current (29.516), Machining time (20.637) and Gap distance (6.806).

## CONCLUSIONS

This paper has discussed the feasibility of machining copper alloys by EDM to produce micro-holes. Taguchi method has been used to determine the main effects, significant and optimum machining parameters. Based on the results, it can conclude that, the current mainly affects the overcut, then machining time and gap distance. Taguchi method gives systematic simple approach and efficient method for the optimum operating conditions.

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**Table(1) Material properties of copper alloy.**

| | |
|---|---|
| Young Modulus (GPa) | 110-128 |
| Shear Modulus | 140 |
| Tensile Strength (MPa) | 350.50 |
| Density (g/cm$^3$) | 8.94 |
| Melting Point (ºC) | 1084.62 |
| Poisson ratio | 0.34 |

**Table(2) Design of Experiment (Parameters and Levels).**

| Machining control parameter | Symbol | Levels | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Current (A) | C | 4 | 6 | 10 |
| Gap Distance (mm) | GD | 0.3 | 0.4 | 0.5 |
| Machining Time (min) | MT | 5 | 7 | 10 |

**Table(3) Experimental results.**

| Exp. No. | Current (A) | Gap Distance (mm) | Machining Time (min) | Diameter of machined micro-hole (µm) | Diameter of electrode tool (µm) | Overcut (µm) |
|---|---|---|---|---|---|---|
| 1 | 4 | 0.3 | 5 | 200 | 199.58 | 0.42 |
| 2 | 4 | 0.4 | 7 | 300 | 298.96 | 1.04 |
| 3 | 4 | 0.5 | 10 | 400 | 398.53 | 1.47 |
| 4 | 6 | 0.3 | 7 | 100 | 99.95 | 0.05 |
| 5 | 6 | 0.4 | 10 | 210 | 209.11 | 0.89 |
| 6 | 6 | 0.5 | 5 | 85 | 84.97 | 0.03 |
| 7 | 10 | 0.3 | 10 | 120 | 119.88 | 0.12 |
| 8 | 10 | 0.4 | 5 | 70 | 69.99 | 0.01 |
| 9 | 10 | 0.5 | 7 | 75 | 74.98 | 0.02 |

**Table (4) Response Table for Signal to Noise Ratios.**

| Level | Current | Gap Distance | Machining Time |
|---|---|---|---|
| 1 | 1.283 | 17.324 | 25.998 |
| 2 | 19.163 | 13.557 | 19.886 |
| 3 | 30.799 | 20.364 | 5.361 |
| Delta | 29.516 | 6.806 | 20.637 |
| Rank | 1 | 3 | 2 |

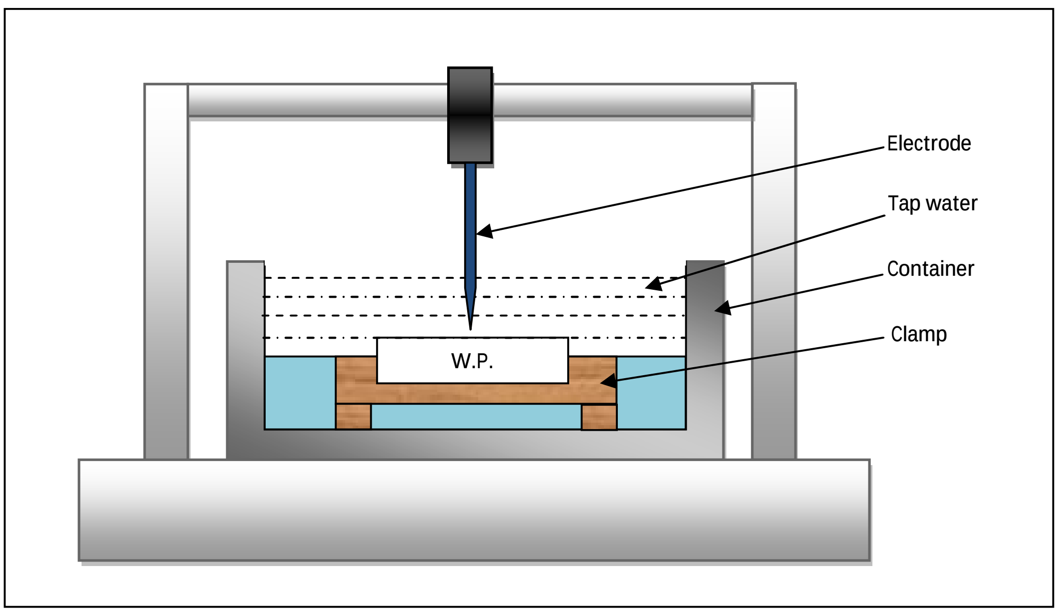


**Figure (1) The schematic diagram of the experiment setup.**

**Figure (2a) EDM system.**

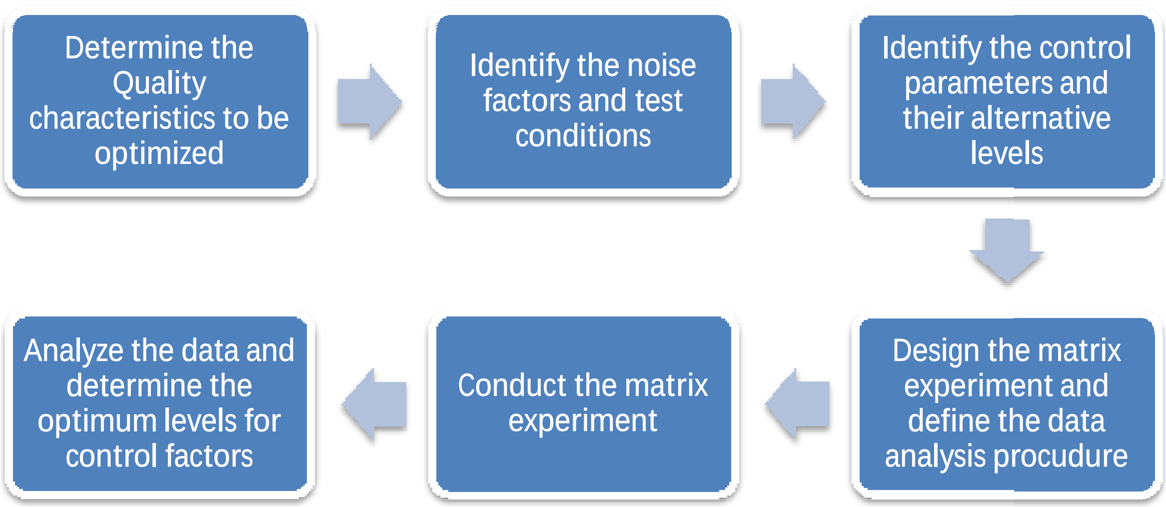


**Figure (2b) Flow chart of Taguchi analysis steps.**

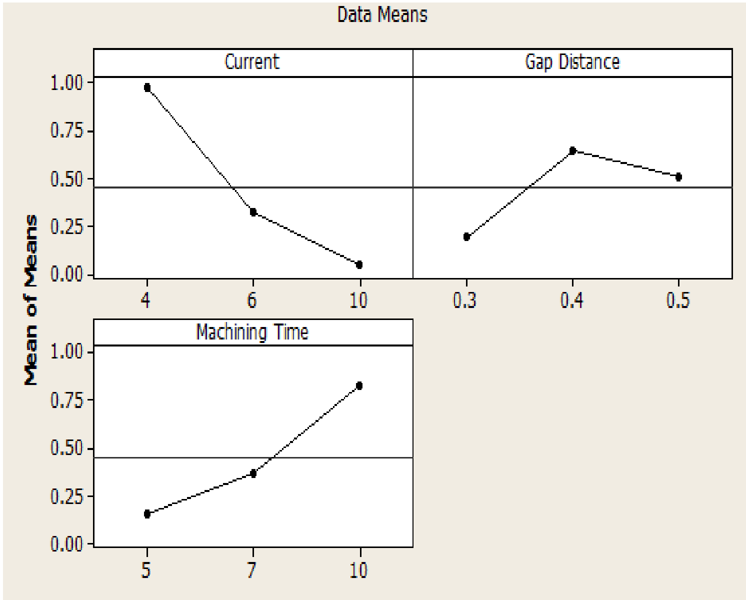


**Figure (3) Main effects plot for means.**

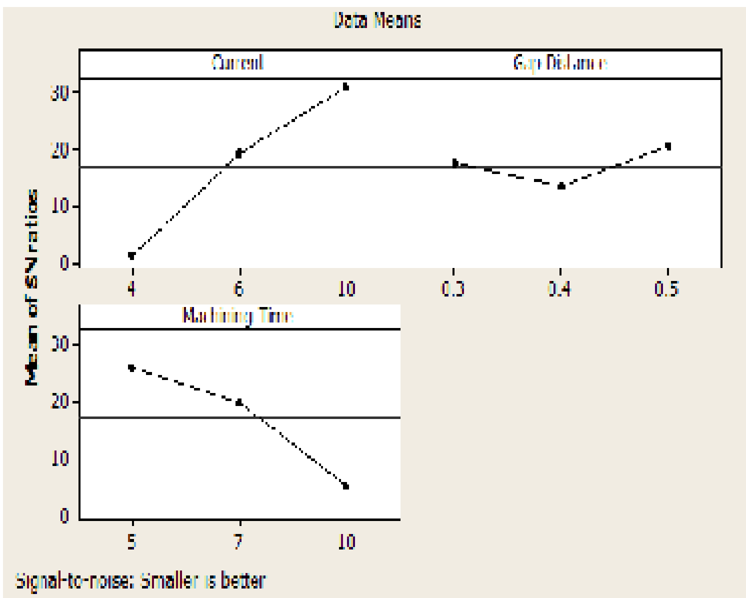


**Figure (4) Main effects plot for S/N ratios for overcut.**