Global Journal of Engineering Science and Research Management

EXPERIMENTAL SETUP DESIGN FOR ELECTROCHEMICAL DISCHARGE MACHINING

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DOI: 10.5281/zenodo.1034488

KEYWORDS: Micromachining, Silicon, EDM, Micro System.

ABSTRACT
New technology requires new machining skills. In the last century, the need for using more and more specialized materials (e.g. silicon, composites or ceramics) greatly increased the already large arsenal of machining technology. The last century also saw the birth of micromachining, in particular micromachining of silicon. At present huge variety of micromachining are available for silicon. Similar situation exists for electrically conductive materials, where, in particular electrochemical machining (ECM) and electrical discharge machining (EDM) are two powerful tools are available. However, several electrically non- conductive materials are also of great interest for many applications. Glass and composite materials are two examples. The technical requirements for using glass in micro system are growing. Medical devices requiring biocompatible materials are only one many of examples.

INTRODUCTION
Ceramics (glass) and plastic materials are playing vital role in the process industries Electrochemical Discharge Machining (ECDM) is the mean to obtain absolute machining parameters using advanced materials up to present situation. Electrochemical Discharge Machining (ECDM) is newly developed hybrid process that combines both ECM and EDM (ECM + EDM = ECDM). It has been successfully used for machining electrically non-conductive advanced engineering materials such as glass and ceramics which has shown the possibility of drilling micro-holes by smaller electrodes efficiently and economically. [1]

DESIGN OF EXPERIMENT (DOE)
In this dissertation work, experiments are performed according to design of experiments. Also, it is process of planning to meet specified objectives. The details of design of experiment are discussed below.

Strategy of experimentation
There are several strategies of experimentation, which have been used by many researchers. The most widely used strategies for experimental analysis includes,
- Best-guess approach
- One-factor-at-a-time approach
- Statistically designed experiments.

Best-guess approach
In this approach an arbitrary combination of factors is selected, then tested and its influence on output response is observed. If this initial 'best-guess' does not produce the desired results, the researchers take another 'guess' at the correct combination of factor levels. This could continue for a long time without guarantee of success. Secondarily, suppose the initial 'best-guess' produces an acceptable result, the researcher is now tempted to stop testing although there is no guarantee that the best solution has been found.

- **One factor-at-a-time**

This approach consist of selecting a starting point or baseline set of levels for each factor, then successively varying a factor over its range with the other factors being held constant at a baseline level. After all tests are performed, a series of graphs usually are constructed showing how the response variable is affected by varying each factor with all other factors held constant. The interpretation of these graphs is straightforward and easy to select the optimal combination of factor levels. However, this strategy fails to consider any possible factor interaction. One factor-at-a-time experiments are always less other method based on a statistical approach to design.

- **Statistical designed experiments**

A correct approach to dealing with several factors is to conduct a statistical designed experiment such as a factorial experiment. In such experimental strategy, factors are varied together instead of one at a time. Such experimental designs based on statistical approach enable the research to investigate the individual effects of each factor (or the main effects) and to determine whether the factors interact. To assess the effect of input parameters on output response variables, large numbers of experimental run are required and therefore, is a time consuming task, large numbers of experimental (DOE) methods are widely used to overcome this problem. The application of DOE requires careful planning, product layout of the experiment, and expert analysis of results Therefore, considering the above aspects, the experiment is designed using Taguchi method based design of experiments methodology as elaborated below.

TAGUCHI METHOD BASED DESIGN OF EXPERIMENTS

Among the available methods, Taguchi design is one of the most powerful DOE methods for analyzing of experiments. It is widely recognized in many fields particularly in development of new products and processes in quality control. Taguchi method-based design of experiments involved following steps.

Definition of the problem

A brief statement of the problem under investigation is “Material Removal Rate in drilling holes by using Electro-chemical discharge machining process”.

- **Identification of the noise factors**

The environment in which experiments are performed is the main external source of variation of performance of ECDM process. Some examples of the environmental noise factors are temperature, vibrations human error in operating the process.

- **Selection of response variables**

In any process, the response variables need to be chosen so that they provide useful information about the performance of the process under study. The response variables chosen for study is material removal rate (MRR).

SELECTION OF THE PROCESS PARAMETERS

The process parameters can be divided into two categories i.e. electrical and non-electrical parameters major electrical parameters are voltage ,current ,pulse duration and electrolyte concentration non electrical ECDM process parameters such as inter-electrode gap tool work piece gap and electrode rotation .Due to limitations of experimental setup we have selected three parameters such as voltage ,electrolyte concentration and tool work piece, gap.

- **Factors considered for parametric study**

There are various factors which affect during machining on electrochemical machining such as inter-electrode gap, tool work piece gap and electrode rotation voltage, current, pulse duration and electrolyte concentration. Whatever the trial experiments carried out shows that voltage is the main factors for studying the experiment conditions .the literature review states that voltage, electrolyte concentration, inter-electrode gap and the spark intensity have major effect on machining parameters like material removal rate, tool wear rate, that’s why we have selected these three parameters namely voltage, electrolyte concentration, inter-electrode gap for parametric study.

- **Selection of machining process parameters**

Experiments were performed using ECDM setup. The initial machining parameters were we as follows: applied voltage (50 V), electrolyte concentration (20%) and inter-electrode gap (30 mm).After performing the basic experiments it was found that the feasible range of applied voltage was 40-60 V, the electrolyte concentration range 10-30% and the inter-electrode gap range 20-40mm .In the present parameter design, three levels of each machining parameters were selected.

- **Identification of orthogonal array matrix**

The orthogonal array used for preliminary experimentation was L_9 .because selected parameters for the preliminary experiments were only with only with three levels. The orthogonal array decided by formula L^P gives the value 3^3=9. Where L is number of levels chosen for process parameters and P is number of process parameters. The final experiment was also conducted usingL9orthogonal array. Therefore, the Taguchi method has great potential in the area of low cost experimentation thus it becomes an attractive and widely accepted tool to engineers and scientists.

- **Selection of Orthogonal array Matrix experiment**

The tool degrees of freedom (DOFs) for experiments are calculated first to select an appropriate orthogonal array for the experiment. The applied voltage, electrolyte concentration and inter – electrode gap are the three factors and each factor has three levels considered for ECDM experiment. With three factors at three levels, the total DOFs is 7[1+3x (3-1)]. In the present study, the interaction between the machining parameters is neglected. From the value of DOFs=7, it is concluded that at least seven experiments are to be conducted to estimate the effects of each machining parameters. After knowing the value of total DOFs, the next step is to select an appropriate orthogonal array. The standard orthogonal array which has at least three numbers of columns at three levels is selected. Hence, the selected standard orthogonal array is L_9 which has four three-level columns and nine rows. This array has total eight DOFs and it can handle four three-level machining parameters. Each machining parameter can be assigned to a column and nine machining- parameter combinations are available inL_9 orthogonal array matrix experiment. Therefore, only nine experiments are required to be conducted as per L_9 orthogonal array to study the effect of machining parameters on the parameters on the performance of ECDM process. Since the L_9 orthogonal array has four columns; one column of the array is left empty for the error of experiments, and orthogonality is not lost by letting one column of the array remain empty.[6].

- **Measurement of machining performance**

Experiments were conducted as per designed experimental plan and the performance or responses were measured for each experimental run. The amount of material removed (MR) was measured by taking difference in weight of the specimen before machining (W1) and weight of the specimen after machining (W2).the MRR can be calculated as $\frac{MRR}{T}$ or $\frac{W1-W2}{T}$

Where,

T = machining time.

W1 = before machining weight

W2 = after machining weight

- **Analysis of signal –to- noise ratio**

In Taguchi method, S/N ratio is used to measure the quality characteristics deviating from the desired value. Term signal represents the desirable mean value of the output characteristics and the term noise represents the desirable value (i.e. standard deviation) for the output characteristics. In order to obtain optimal machining performance, the higher the better quality characteristics for MRR are considered. [6].

- **Larger is better characteristics**

Data sequence for MRR, which is higher-the-better performance characteristics, is preprocessed as per equation (5.1)

$$\frac{S}{N} = -10\left(\frac{1}{n}\right)\left(\sum\left(\frac{1}{y^2}\right)\right) \quad \text{......... (eq.1)}$$

Where, ‘y’ is value of response variables and ‘n’ is the number of observations in the experiments. Since the experimental design is orthogonal, it is possible to sort out the effect of each machining parameter at different levels. The mean S/N ratio for the applied voltage (A) at levels 1,2 and3 can be calculated by averaging the S/N ratios for the experiments 1-3, 4-6 and 7-9, respectively.

ECDM SET UP FOR EXPERIMENTATION

The voltage can be varied in the range 10V to 90V, the inter-electrode gap can be varied as a 20mm to 40mm. the minimum requirement of the electrolyte solution to work the circulation system efficiently and satisfactorily is 200ml. Based on preliminary experimental work, the final experiment was performed on soda lime glass work piece with copper material as tool electrode and auxiliary electrode. The amount of material removed (MR)was measured by taking difference in weight of the specimen before machining and weight of the specimen after machining.

CONCLUSION

The experimentation was designed and performed by Taguchi method. Analysis was done using software known as 'Minitab 15'. The experiment was performed on soda lime glass using KOH as electrolyte of different concentration and copper rod were taken as tool electrodes. Electrolyte concentration, voltage and tool work-piece gap were taken as process parameters and Material removal rate (MRR) was taken as response variable.

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