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Analysis of Machining Parameters for Dimensional Accuracy in EDM using Taguchi's Doe

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***Abstract*-This research outlines the Taguchi's Parameter Design Approach which is applied to optimize machining parameters of dimensional accuracy in Electric Discharge Machining (EDM). Analysis of variance (ANOVA) is used to study the effect of process parameters on machining process. The procedure followed eliminates the need for repeated experiments, saves time and conserves the material. The machining parameters investigated are Discharge current, Pulse Duration and Pulse control. The selection of the mild steel was made taking into account its use in almost all industrial applications. The main objective is used to find the important factors and combinations of factors influencing the machining process to achieve the best dimensional accuracy (Nominal value of the size of drilled hole). The study shows that percentage contribution of the parameters reveal that the influence of the Pulse control in controlling both mean and variation of materials removal rate is significantly larger than that of discharge current and pulse duration.**

Key Words: EDM, Taguchi method, ANOVA, Discharge current, pulse control, pulse duration.

1. INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used nonconventional material removal processes. The material in this process is removed by a succession of electrical discharges, which are occuring between the electrode and the workpiece. There is no direct contact between the electrode tool and the workpiece. These are submersed in a dielectric liquid such as kerosene or deionised water. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage. The electric discharge machining process is widely used in the aerospace, die manufacturing, automobile and moulds industries to machine hard metals and its alloy.In dates back to 1770, English chemist Joseph Priestly discovered the erosive effect of electrical discharges on metal. In 1943 after a long time, at the Moscow University where B.R. and N.I. Lazarenko decided to exploit the destructive effect of electrical discharges for constructive use. They created a controlled process of machining to machine metals by vaporizing material from the surface of workpiece. Since then, EDM technology has developed rapidly and become indispensable in manufacturing applications such as die and mould making, prototyping, micro-machining, etc. In 1950s the RC (resistance–capacitance) relaxation circuit was introduced, in which provided the first consistent dependable control of pulse times and also a simple servo control circuit to automatically find and hold a given gap between the electrode (tool) and the workpiece. In the 1980s, CNC EDM was introduced which improved the efficiency of the machining operation.

The basic principle in EDM is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in the dielectric fluid. For avoiding electrolysis of the electrodes during the EDM process the insulating effect of the dielectric fluid is very important. A spark is produced is at the point of smallest inter-electrode gap by a high voltage, overcoming the strength dielectric breakdown strength of the small gap between the cathode and anode at a temperature in the range of 8000 to 12,000 °C. Erosion of metal from both electrodes takes place there. Spark duration of each spark is very short. The complete cycle time is usually few micro-seconds (μs).The frequency of pulsating direct current supply is about 20,000–30,000 Hz is turned off. There is a sudden reduction in the temperature which allows the circulating dielectric fluid to flush the molten material from the workpiece in the form of microscopic debris. The capacitor is recharged, after each discharge from DC source through a resistor. Also the spark that follows is transferred to the next narrowest gap in Fig.1. The cumulative effect of a succession of sparks spread over the entire workpiece surface leads to machining to a shape, or erosion which is approximately complementary to that of the tool.

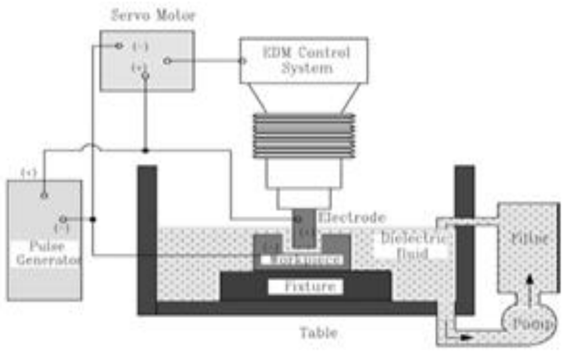

Fig 1. Schematic Diagram of EDM

A servo system, which compares the gap voltage with a reference value, is employed to ensure that the electrode moves at a proper rate to maintain the right spark gap, which retract the electrode if short-circuiting occurs. The circuit designed by Lazarenko RC does not give good material removal rate (MRR), and higher MRR is possible only by sacrificing surface finish. As indicated in Fig.1 the increase in voltage of capacitor should be larger than the breakdown voltage and hence great enough to create a spark between electrode and workpiece, at region of least electrical resistance, which generally occurs at the smallest inter electrode gap. This has been achieved with advent controlled pulse generator.

2. LITERATURE REVIEW

Dhar and Purohit[1] evaluates the effect of current (c), pulse-on time (p) and air gap voltage (v) on TWR, MRR, and ROC of EDM with Al–4Cu–6Si alloy–10 wt. % SiCP composites.The significant of the models were checked using technique ANOVA and finding the ROC, TWR and MRR increase significant in a non-linear fashion with increase in current. B.Mohan and Satyanarayana[2] evaluates the effect of the EDM Current, pulse duration, electrode marital polarity and rotation of electrode on TWR, metal removal rate and SR, and the value in EDM of Al-Sic with 20-25 vol. % SiC. Irrespective of the electrode material volume present of SiC and polarity of the electrode the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration. By increasing the speed of the rotation electrode resulted in a positive effect with MRR, TWR and better SR than stationary. Yan-Cherng et.al [3] the effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of SKH 57 high-speed steel were investigated. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. During the experiment MRR increases with peak current MRR initially increased to a peak at around 100 μs, and then fell. Narender Singh et al.[4] discuss the evolution of effect of the EDM current (*C*), Pulse ON-time (*P*) and flushing pressure (*F*) on MRR, TWR, taper (*T*), ROC, and surface roughness (SR) on machining as-cast Al-MMC with 10% SiCp . An L27 OA, for the three machining parameters at three levels each, was selected to conduct the experiments. The ANOVA was performed and the optimal levels for maximizing the responses were established. Biing Hwa et al.[5] has discuss the investigates the feasibility and optimization of a rotary EDM with ball burnishing for inspecting the machinability of Al2O3/6061Al composite using the Taguchi method. This EDM process approaches both a higher machining rate and a finer surface roughness. Lee and X.P.Li [6] showed the effect of the machining parameter in EDM of tungsten carbide on the machining characteristics. This study confirms that there exists an optimum condition for precision machining of tungsten carbide although the condition may vary with the composing of martial, the accuracy of the machine and other external factor.

Puertas and Luishas [7] define the optimization of machining parameter for EDM of Boron carbide of conductive ceramic materials. Tsai et al [8] have working material of graphite, copper and copper alloys are widely using EDM because these materials have excellent electrical conductivity, thermal conductivity and high melting temperature. According to the experimental results, a mixing ratio of Cu–0wt%Cr and a sinter pressure of 20 MPa obtained an excellent MRR. Sameh S. Habib [9] Study of parameter in EDM by using the RSM, the parameter like gap size, SR, MRR and TWR and relevant experimental data were obtained through experimentation. The optimal combination of these parameters was obtained for achieving controlled EDM of the workpiece and finding the MRR increases with an increase of pulse on time, peak current and gap voltage and MRR decrease with increasing of SiC%. Sohani et al.[10] discussed about sink EDM process effect of tool shape and size factor are to be considering in process by using RSM process parameters like pulse off-time, pulse on-time, discharge current and tool area. From the parametric analysis, it was observed that the interaction effect of discharge current and pulse on-time is highly significant on MRR and TWR.

3. DESIGN OF EXPERIMENTS

The objective of this study is to analyze the machining parameters for dimensional accuracy in EDM using Taguchi methodology. In the present work Taguchi's parameter design approach is used to study the effect of process parameters- discharge current, pulse duration, pulse control on dimensional accuracy while machining mild steel. Taguchi Method are statistical approach developed by Genichi Taguchi to improve the quality of manufactured products, and more recently also applied to marketing, engineering, advertising and biotechnology. Taguchi recommends orthogonal arrays (OA) for lying out of experiments The optimum condition is identified by studying the main effects of each of the parameters. The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments in determining the percent contribution of each parameter against a stated level of confidence. Detailed study of ANOVA table for a given analysis helps to determine which of the parameters need control. Taguchi's work includes three principle contributions to statistics

1. A specific loss function
2. The philosophy of off-line quality control
3. Innovations in the design of experiments.

The Taguchi-based experimental design used in this study is an L9 orthogonal array.

Signal-to-Noise ratios (S/N ratio)
The parameters that influence the output can be categorized into two classes, namely controllable (signal) factors and uncontrollable (or noise) factors. The S/N ratio is used to measure the quality characteristic deviating from the desired value. The S/N ratios for dimensional accuracy can be calculated as given equation.

$$\left(\frac{S}{N}\right)_{NB} = -10 \log \frac{1}{R}\left[\sum_{j=1}^{R}(y_j - y_0)^2\right]$$

Where
Y_J= value of the characteristics in an observation j
R = number of repetitions in a trial
Y_0= nominal value of characteristic

4. EXPERIMENTAL DETAILS

The experiments were conducted on a An EDM machine (T-3822) installed at Laxmi Precision Screw Ltd., Rohtak, Haryana.

Model : T-3822

4.1 MACHINE

Total height	:	1300 mm
Width	:	730 mm
Depth	:	840 mm
Net weight approx.	:	325 kg.

4.2 WORK HEAD

Travel of the quill	:	150 mm
Reading accuracy of the dial gauge	:	0.01 mm

4.3 CO-ORDINATE TABLE

Mounting surface (L×B)	:	380 × 220 mm
Maximum workpiece height	:	125 mm
Maximum workpiece weight	:	80 Kg.
Longitudinal travel (x-axis)	:	200 mm
Transverse travel (y-axis)	:	125 mm
Maximum table-quill distance	:	340 mm
Minimum table-quill distance	:	190 mm

4.4 WORK TANK

Length	:	600 mm
Width	:	350 mm
Height	:	240 mm

4.5 STORAGE TANK

Length	:	1000 mm
Width	:	500 mm
Height	:	675 mm
Capacity	:	150 ltrs.
Weight without dielectric	:	65 Kg.

4.6 WORKING PARAMETERS

Machine current maximum (A)	:	12
Pulse duration each	:	2 range of 54 µS (vary from 2 µS to 650 µS)
Pulse control	:	8 positions

4.7 OPERATIONAL DATA

1) ELECTRODE

Material	:	Pure Copper
Size	:	φ26.62 mm

2) WORK PIECE

Material	:	Mild Steel
Size	:	(250*50*10) mm
Dielectric Fluid	:	Clean Kerosene

Fig. 2: Dielectric tank with Stirrer attachment

The selection of parameters of interest was based on some experiment preliminary .The following process parameters were thus selected for the present work:
(a) Discharge current – (A),
(b) Pulse duration – (B),
(c) Pulse control – (C),
The discharge current, pulse duration and pulse control were selected from within the range of parameters for machining mild steel. Pure copper electrode was chosen to find the best optimum discharge current, pulse duration and pulse control among the chosen one.

Table 1: Selection of process parameters

Process Parameter	Parameter Designation	Levels		
		L1	**L2**	**L3**
Discharge Current(A)	A	04	07	11
Pulse Duration(μS)	B	162	324	486
Pulse Control	C	02	05	08

Each three level parameter has 2 degree of freedom (DOF) (Number of level – 1), the total DOF required for three parameters each at three levels is 6[=3x (3-1)]. As per Taguchi's method the total DOF of the OA must be greater than or equal to the total DOF required for the experimentation. So an L_9 OA (a standard 3- level OA) having 6(=9-3) degree of freedom was selected for the present analysis and Minitab 15 software was used for graphical analysis of the obtained data.

Table 2: L_9 OA with responses

Column	1	2	3	Response (Raw Data) (mm)			S/N Ratio (db)
Sr. No.	A	B	C	R1	R2	R3	$\frac{S}{N} = -10 log \frac{1}{r}[\sum_{i=1}^{r}(y_i - y_o)^2]$
1	1	1	1	26.62	26.63	26.62	44.77
2	1	2	2	26.64	26.64	26.63	35.23
3	1	3	3	26.66	26.67	26.65	27.78
4	2	1	2	26.65	26.67	26.64	27.78
5	2	2	3	26.67	26.67	26.66	26.58
6	2	3	1	26.63	26.64	26.62	37.78
7	3	1	3	26.68	26.69	26.66	24.73
8	3	2	1	26.64	26.65	26.63	33.31
9	3	3	2	26.66	26.68	26.65	26.92

5. RESULT AND DISCUSSION
ANALYSIS OF RAW DATA

The analysis of variance was carried out for a 95% confidence level. The ANOVA shows that, the *F* value corresponding to all parameters are greater than the tabulate value of $F_{0.05}$. The main purpose of the analysis of variance is to investigate the influence of design parameters on optimal dimensional accuracy by indicating the parameters that significantly affect the quality characteristics of the machined surfaces. The given analysis provides the relative contribution of machining parameters in controlling the response of machining performance criteria i.e. dimensional accuracy during mild steel machining. Table 3 shows that the discharge current, pulse duration, and pulse control are responsible and have influence on dimensional accuracy while machining with copper electrode. The influence of pulse control is the most significant as according literature review. And the influence of discharge current is significant and pulse duration is less influencing factor as compare to other on the dimensional accuracy during machining of mild steel.

Table: 3 Response Table for Means

Level	Discharge current	Pulse duration	Pulse Control
1	26.63	26.65	26.63
2	26.65	26.64	26.64
3	26.66	26.65	26.67
Delta	0.03	0.01	0.04
Rank	2	3	1

Predicted values for optimal machining condition for dimensional accuracy

For Mean value of drilled hole=26.6044mm

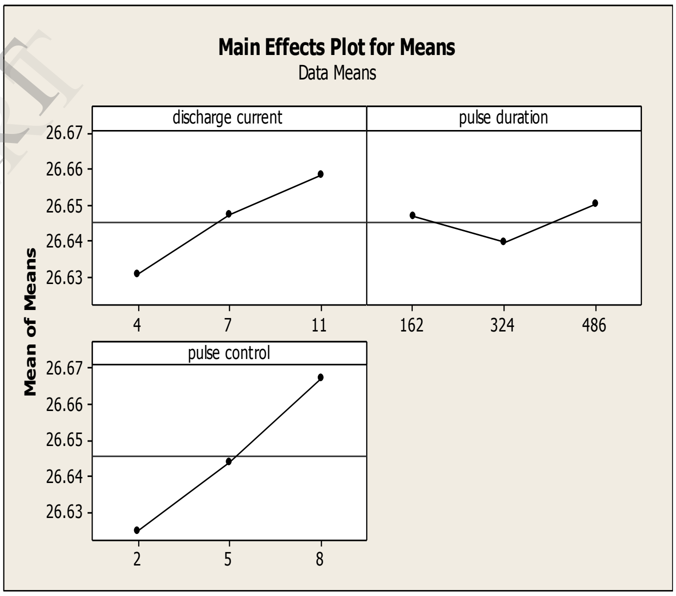

Fig.3: Main Effect plot for mean

Table4: Factor levels for predictions

discharge current	pulse duration	pulse control
4	324	2

6. CONFIRMATION EXPERIMENTS

Table5: Confirmation Test

Sample	Ra (μm)
1	26.5815
2	26.5923
3	26.6112
4	26.5911
5	26.6010
Mean Ra(μm)	**26.5954**

CONCLUSION

The present research can be concluded by the following steps:

(1) After analyzing the average plot for the raw data the optimal machining conditions for the selected quality characteristics, dimensional accuracy, are:
Discharge Current (A, level 1) : 4amp.,
Pulse Duration (B, Level 2) : 324μS
Pulse Control (C, Level 1) : 02

(2) The following are the percentage contributions of the parameters to the variations of Dimensional Accuracy in machining of Mild Steel part using pure Copper Cylindrical tool.

FOR RAW DATA
Discharge Current : 17.65%
Pulse Duration : 6.66%
Pulse Control : 59.51%

The percentage contribution of the parameters reveal that the influence of the Pulse control in controlling both mean and variation of materials removal rate is significantly larger than that of Discharge current and pulse duration.

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BIOGRAPHIES

Bhupender Singh received his B.E degree in Mechanical Engineering from P.D.M.C.E, Bahadurgarh, in 2008, and the M.Tech degree in Manufacturing Technology and Automation from S.B.M.N.E.C, M.D.U University, Rohtak, Haryana in 2011. He is Assistant Professor, with Department of Mechanical Engineering. in Panipat Institute of Engineering & Technology, Samalkha near Panipat (Haryana). He has more than 3 years teaching experience.

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