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Optimization of Die-Sinking EDM Process Parameters with Steel Electrodes Using ANOVA

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ABSTRACT

Efficiency and quality are two essential viewpoints have turned out to be extraordinary worries in the present aggressive worldwide market. Each creation / fabricating unit primarily centers on these territories in connection to the procedure and item created. Legitimate choice of assembling conditions is a standout amongst the most critical perspectives in the Electrical Discharge Machining process, as these conditions decide vital attributes, for example, Material Removal Rate (MRR) and Tool Wear Rate (TWR). This paper deals with the optimization model to investigate the effect of Voltage and Duty Cycle in Die-Sinking EDM (DSEDM). In this experiment, MRR and TWR in machining of Copper using pair of steel electrodes with straight polarity have been calculated. Based on the experiments and using Taguchi's design of experiments response tables and graphs are made. For high MRR and low TWR the most significant factor to be voltage. The optimum parameters at Voltage 55V, 70% Duty Cycle, where the MRR becomes high and at Voltage 55V, 70% Duty Cycle the TWR reduces significantly.

KEYWORDS: Die-Sinking EDM, Twin Tool Setup, Material Removal Rate, Tool Wear Rate, ANOVA.

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I. INTRODUCTION

Electrical Discharge Machining (EDM) is a standout amongst the most widely utilized nonconventional fabricating forms utilized for hard materials which are extremely hard to machine with traditional systems. EDM is some of the time alluded to as spark machining, spark eroding, burning, Die sinking or wire erosion. This is a manufacturing process whereby a coveted shape is acquired utilizing electrical discharges (sparks) produced between the tool electrode and the workpiece electrode immersed in a dielectric fluid.

The electrical sparks are produced to expel the workpiece material through dissolving and dissipation process and results in the production of miniaturized scale includes on any conducting and semiconducting designing materials regardless of their size, shape and mechanical properties like quality, hardness, hard-headedness and so on. A portion of the building materials machined utilizing EDM are tungsten, tungsten carbide, copper, copper tungsten combination, silver, metal, graphite, beryllium copper amalgam, hardenable steels and so forth.

The working principle of Die-Sinking EDM is same as that of ordinary EDM yet the use of small electrode size and miniaturized scale MRR and TWR are the main contrasts amongst customary and Die-sinking EDM. Figure 1 demonstrates the working principle of EDM.

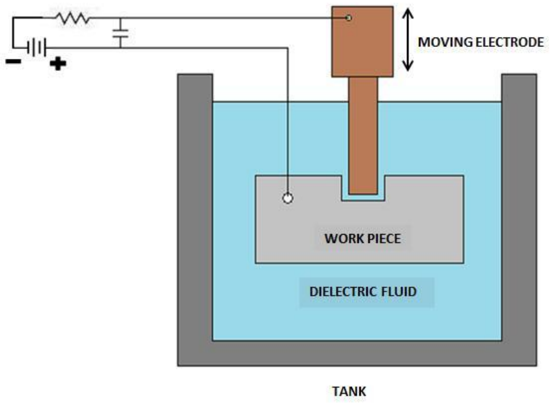


Figure 1 Working Principle of EDM

It comprises of an Electrode (cathode) and work piece (anode) isolated by a little gap known as spark gap and are submerged in a dielectric (electrically non-directing) liquid, for example, hydrocarbon oil, lamp fuel or de-ionized (DI) water. The electrical vitality is provided between the cathodes and when potential distinction is adequately high, the dielectric separates and a transient start release happens over the hole width. Due to softening and vaporization, disintegration of material happens furthermore, the pit is created as the shape is precisely same as that of tool shape.
In this paper, the experimental setup of Die-sinking EDM with Twin apparatus setup created for machining of holes on copper workpiece with a couple of steel and copper electrodes in a single stream. Through holes are created on copper workpiece of size 1 mm thickness with two different tools (steel and copper) of size 2 mm diameter utilizing De-ionized water as dielectric medium. The ideal parameters for most extreme MRR and least TWR are acquired by varying the control factors like Voltage and Duty Cycle.

II. METHODOLOGY

Taguchi's strategy is an effective method for the plan of a brilliant framework. It gives a productive as well as an orderly way to deal with improves plans for execution and quality. Moreover, Taguchi parameter configuration can lessen the change of framework execution. The experiment is governed by the following steps are:

- Select the appropriate orthogonal array and assign these parameters to the orthogonal array.
- Perform the experiments based on the arrangement of orthogonal array.
- Analyze the experimental results using ANOVA and S/N Ratios

2.1 Experimental Design

- **Process Parameter Selection:** Process parameters and their ranges are determined by the research work. The parameters are identified for the experiments such as Voltage and Duty Cycle.
- **Orthogonal array selection:** To select an appropriate orthogonal array for the experiments, on the basis of parameter selection and its levels. Here we have two parameters and three levels are selected.
- **Conduct the experiment and Recording of responses:** Nine experimental runs are conducted as per the Taguchi's L_9 orthogonal array. The test runs are carried out at random to avoid a systematic error creeping into the experimental procedure.
- **Analysis using ANOVA:** The analysis of the performance parameters can be obtained by using analysis of variance and find the most critical factors for getting the optimum performance parameters.

III. EXPERIMENTATION

3.1 Experimental Setup

An indigenous experimental setup has been built to carry out Electro Discharge machining process with the stepper motor tool feed mechanism. It consists of different units as

- **Tool Feeding Unit:** Stepper Motor is used to develop a feedback and to maintain the constant gap between the tool and the work piece. The unit consists of the components like
  - Twin Tool Setup
  - Stepper Motor
  - Micro guide way

- **Dielectric and Recirculation unit:** Filtering and recirculation unit is developed to flush the debris and to get good machining. The unit consists of the components like
  - Dielectric Beaker
  - Work piece holder
  - Pump and Filter
- **Pulse Generation and Control Unit:** It is designed to provide pulses of specified frequency and duty cycle to the tool and the work piece. The unit consists of the components like
  - Oscilloscope.
  - Pulse Width Modulator
  - DC Power Supply.

The following Figure 2 shows the developed Die-sinking EDM setup and its parts and Table 1 provides the detailed specifications of developed Die-sinking EDM (DSEDM) setup.

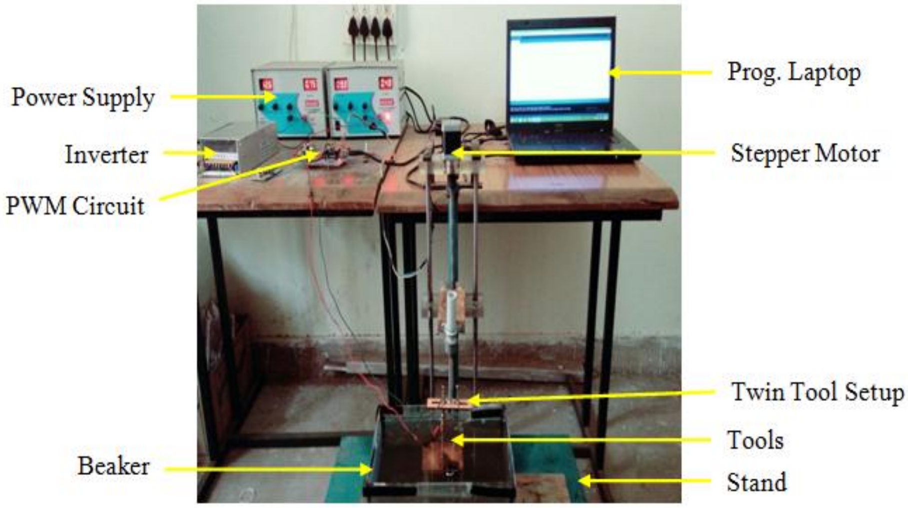


Figure 2 Experimental Setup of DSEDM

Table 1 Specifications of developed DSEDM

S. No.	Parts	Specification
1	Hole Features	Through holes, Blind holes. Minimum feature size: 50 µm; Depth: upto 4 mm
2	Workpiece material	Any electrically conducting materials and semiconducting materials
3	Tool Material	Cu, SS
4	Dielectric and Recirculation	Dielectric Beaker : 220X220 mm square and 80 mm depth Pump : Gear pump, 12 V DC supply Flow Control: Through variable voltage supply Flow rate : 220 ml/min. to 2.2 l/min Dielectric Filter: 0.5 µm
5	Tool Feed	Feed Mechanism : Stepper Motor Type of control : Analog Maximum displacement: 400 µm Maximum load carrying capacity: 38N Response Time: 1.01 ms Resolution: 4 nm Drive System: Voltage Drive(0-150V)
6	Power input	Voltage: up to 60V Pulse Generator: Transistor type Pulse frequency range: 1 KHz – 5 KHz Duty Cycle range : 50% - 70%

3.2 Twin Tool Setup

The Twin Tool Setup is outlined and created for machining of a pair of holes in a copper workpiece in a solitary stream. It contains distinctive parts, which are utilized to frame a twin device gadget. The twin device setup fundamentally comprises of Gripping Rod (Threaded write), GI Sheet/Plywood (120x20x3 mm thickness), Micro drill chucks (Qty.: 2 No's), Screw Fasteners (Nuts, Bolts and Washers) and Electrodes (Tools). The Twin Tool Setup for the experimentation is appeared in Figure 3. With this setup, it can able to produce pair of holes at numerous sizes at variable distances. There are wide assortment of utilizations in machining of a pair of holes in Fuel Injection Components, Fuel cells, Catheter gap boring, Ink Jet Printer Nozzles and so forth.

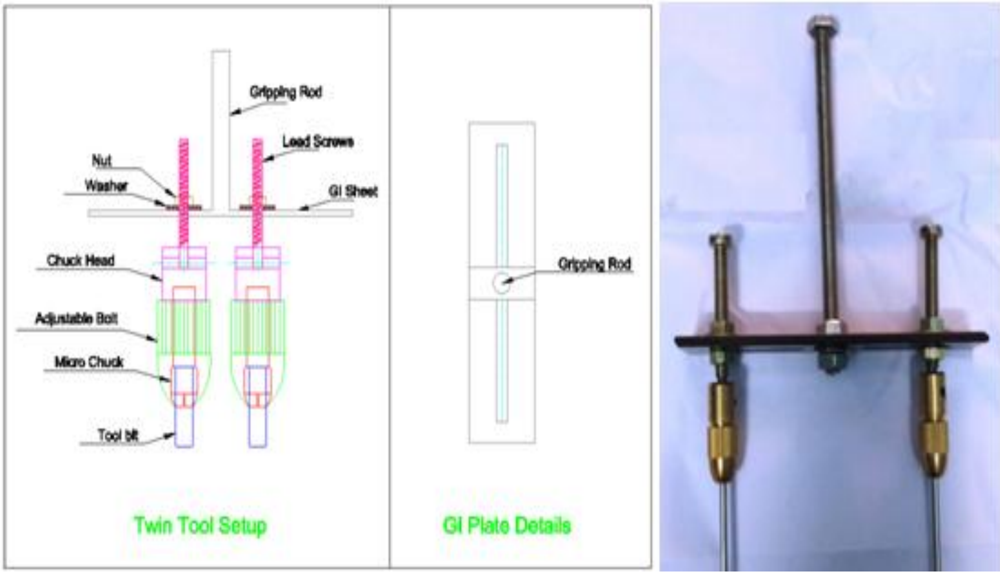


Figure 3 Schematic View of Twin Tool Setup

3.3 Experimentation

A set of experiments are conducted based on taguchi design of experiments for machining of holes on copper workpiece using pair of steel tools in a single stream with De-ionized water is used as dielectric medium. The experimental details are as follows.

Through holes are machined on copper workpiece by varying the control factors such as Voltage and Duty Cycle. The selected control parameters and their levels are listed in Table 2.

Table 2 Machining Conditions and Control Parameters

Machining Conditions			
Workpiece material	Copper		
Thickness of workpiece	1 mm		
Electrode material	Steel (2 No's)		
Size of electrodes	Ø2 mm		
Duty Cycle	50% - 70%		
Voltage	35V – 55V		
Control parameters	**Levels**		
	1	**2**	**3**
Voltage (V)	35	45	55
Duty Cycle (%)	50	60	70

The data of responses like machining time, MRR and TWR are calculated and recorded in Table 3.

Table 3 Experimental Reading

S. No.	**Voltage (V)**	**Duty Cycle (DyC)**	**Machining Time (Min.)**	**Hole Size (mm)**		**MRR (mm^3/min)**	**TWR (mm^3/min)**	
				H_1	**H_2**		**T1**	**T2**
1	35	50%	81.5	2.044	2.185	0.176	0.324	0.324
2	35	60%	66.5	2.117	2.097	0.215	0.381	0.381
3	35	70%	41	2.084	2.069	0.349	0.627	0.627
4	45	50%	26	2.172	2.015	0.551	0.840	0.840
5	45	60%	23.5	2.088	2.003	0.609	0.857	0.857
6	45	70%	27	2.006	2.136	0.530	0.775	0.775
7	55	50%	19	2.181	2.130	0.754	1.040	1.040
8	55	60%	15.5	2.050	2.002	0.924	1.182	1.182
9	55	70%	10.5	2.018	2.085	1.364	1.657	1.657

Figure 4 shows the microscopic images of through holes with 100X and 150X magnification taken from Video Measuring System (VMS) for different voltages and duty cycles.

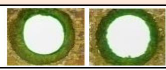
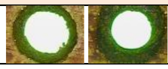
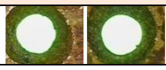
At 35V		
		
50% DyC H_1= 2.044, H_2= 2.185	60% DyC H_1=2.117, H_2= 2.097	70% DyC H_1=2.084, H_2=2.069
At 45V		
		
50% DyC H_1=2.172, H_2= 2.015	60% DyC H_1= 2.088, H_2= 2.003	70% DyC H_1= 2.006, H_2= 2.136
At 55V		
		
50% DyC H_1= 2.181, H_2= 2.130	60% DyC H_1= 2.050, H_2= 2.002	70% DyC H_1= 2.018, H_2= 2.085

Figure 4 Images of holes obtained from VMS

IV. RESULTS AND DISCUSSION

In this present research work, the experiments have 2 variables at 3 different levels. The experiments are conducted based on Taguchi experiment with a L_9 orthogonal array and calculate S/N ratios for MRR and TWR.

4.1 Influences of MRR

The S/N ratios for MRR are calculated as given in Equation (1). Taguchi method is used to analysis the result of response of machining parameter for larger is better criteria. For larger is better:

$S/N = -10 * \log_{10}(\Sigma(1/Y^2)/n)$ ------- (1)

Where, y_i = experimental value in the i^{th} , n = number of replications. Where the S/N ratios calculated from observed values, y_i represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-9 is conducted.

Table 4 S/N Ratio Table for MRR

Level	Voltage	Duty Cycle
1	-12.5282	-7.5731
2	-4.9997	-6.1151
3	-0.1476	-3.9872
Delta	12.3805	3.5859
Rank	1	2

Table 5 Analysis of Variance for S/N ratio of MRR

Source	DF	Adj SS	Adj MS	F	P	% Cont.
Voltage (V)	2	0.89218	0.44609	15.08	0.014	80.362
Duty Cycle	2	0.09966	0.04983	1.68	0.295	8.976
Error	4	0.11836	0.02959			10.662
Total	8	1.11020				100

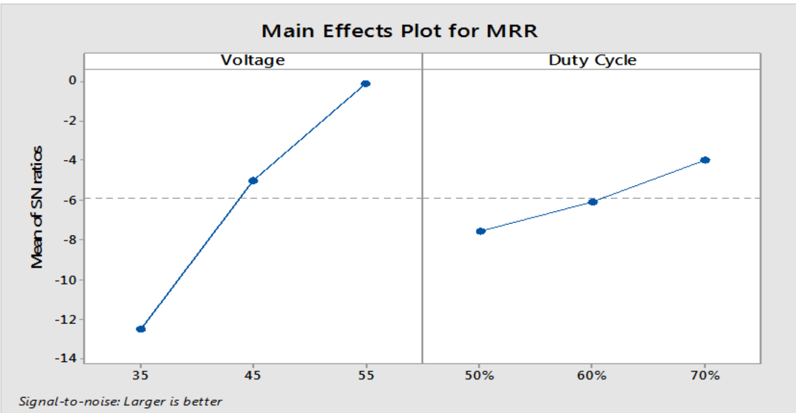


Figure 5 Main Effects plot for MRR

From Table 4 and Figure 5, it is observed that the optimum parameters for larger MRR is obtained at 55 Voltage and 70% duty cycle and also from Anova Table 5, it is observed that the most influential parameter is Voltage (80.362%)

4.2 Influences of TWR

The S/N ratios for TWR are calculated as given in Equation (2). Taguchi method is used to analysis the result of response of machining parameter for smaller is better criteria. For smaller is better:

S/N = -10 *$\log_{10}(\Sigma(Y2)/n)$ ------- (2)

Where, y_i = experimental value in the i^{th} , n = number of replications. Where the S/N ratios calculated from observed values, y_i represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-9 is conducted.

Table 6 S/N Ratio Table for TWR

Level	Voltage	Duty Cycle
1	7.4084	3.6543
2	1.6896	2.7565
3	-2.0598	0.6274
Delta	9.4682	3.0269
Rank	1	2

Table 7 Analysis of Variance for S/N ratio of TWR

Source	DF	Adj SS	Adj MS	F	P	% Cont.
Voltage (V)	2	1.0852	0.54258	16.36	0.012	80.409
Duty Cycle	2	0.1318	0.06589	1.99	0.252	9.765
Error	4	0.1327	0.03316			9.826
Total	8	1.3496				100

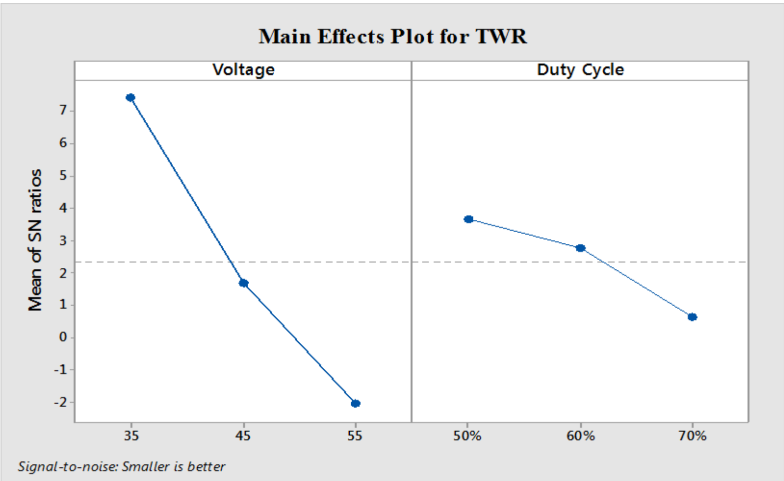


Figure 6 Main Effects plot for TWR

From Table 6 and Figure 6, it is observed that the optimum parameters for smaller TWR is obtained at 55 Voltage and 70% duty cycle and also from Anova Table 7, it is observed that the most influential parameter is Voltage (80.409%)

V. CONCLUSIONS

Based on the research work the following conclusions are drawn:

- In this paper, Twin Tool Setup is developed for machining of pair of holes on Die-Sinking EDM.
- Through holes are produced on copper workpiece with two steel electrodes of size 2 mm diameter by using De-ionized water as dielectric fluid.
- The effects of process parameters on performance parameters like MRR and TWR are discussed in detail and the constituent results are obtained.
- From ANOVA results, it is observed that the most influential parameter for MRR and TWR is voltage.
- From the main effects plot, it is observed that the optimum parameters for maximum MRR and minimum TWR is obtained at 55V and 70% Duty Cycle

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REFERENCES

[1]. Shah Fateh Azam, Dr. D.K. Singh "Optimization of Electrical Discharge Machining Process Parameters Using Genetic Algorithm" International Journal of Engineering Research & Technology, Vol. 2, Issue 9, PP: 3127-3136, ISSN: 2278-0181, Sept 2013

[2]. K. Aruna, Somashekhar S. Hiremath – "Investigation on Machining of Silica Wafer Using Developed Micro-Electrical Discharge Machining (μ-EDM)", International Journal of Engineering Research in Electronics and Communication Engineering, Vol. 4, Issue 4, PP: 55 – 61, ISSN: 2394 – 6849, April 2017

[3]. Rajesh Kumar Porwal, Sanjay Mishra and Basanta Kumar Bhuyan – "Modeling of Hole Sinking Electrical Discharge Micro Machining of Ni-Based Super Alloy Thin Sheet" ELK Asia Pacific Journals – Special Issue, ISBN: 978-81-930411-8-5

[4]. Md. Ashikur Rahman Khan & M. M. Rahman – "An Experimental Investigation on Surface Finish in Die-Sinking EDM of Ti-5Al-2.5Sn" International Journal of Advanced Manufacturing Technology, Issue. 77, PP: 1727 – 1740, 2015

[5]. Brijech Guptha and S.C. Jayswal – "Parametric Optimization of TWR on Die Sinking EDM By Using Taguchi's Approach" International Journal of Mechanical And Production Engineering, Vol. 3, Issue. 10, PP: 102 – 106, ISSN: 2320 – 2092, Oct – 2015

[6]. Samaddar Prasenjeet, B. B. Patel and K. B. Rathod – "Predictive Modeling & Analysis of AISI 1045 Tool Steel in Die Sinking EDM Using Neural Network Approach" International Journal of Engineering Trends and Technology (IJETT), Vol. 4, Issue. 8, PP: 3383 – 3388, ISSN: 2231 – 5381, August 2013

[7]. Upinder Kumar, Abhinavkumar Singh and Rakesh Kumar – "Optimization of Machining Parameters for Tool Wear Rate and Material Removal Rate in CNC Turning by Grey Relational Analysis" International Journal Applied Engineering Research, Vol. 11, Issue. 4, PP: 2771 – 2775, ISSN: 9073 – 4562, $ November 2016

[8]. Bose G.K and Mahapatra K.K – "Parametric Study of Die Sinking EDM Process on AISI H13 Tool Steel Using Statistical Techniques" Advances in Production Engineering & Management, Vol. 9, Issue. 4, PP: 168 – 180, ISSN: 1854 – 6250, December 2014

[9]. J. Jeykrishnan et al. – "Effects of Die Sinking Electro Discharge Machining Parameters on Surface Roughness in Inconel 825 Alloy" Indian Journal of Science and Technology, Vol. 9, Issue. 41, PP: 1 – 5, ISSN: 0974 – 6946, November 2016

[10]. Teepu Sultan, Anish Kumar and Rahul Dev Gupta – "Material Removal Rate, Electrode Wear Rate and Surface Roughness Evaluation in Die Sinking EDM with Hollow Tool through Response Surface Methodology" International Journal of Manufacturing Engineering, Vol. 2014, PP: 1 – 16, 2014

[11]. T. Roy and R.K. Dutta – "Study of the Effect of EDM Parameters based on Tool Overcut Using Stainless Steel (SS 304 Grade)" International Journal of Engineering Trends and Technology (IJETT), Vol. 13, Issue. 5, PP: 196 – 199, ISSN: 2231 – 5381, Jul 2014

[12]. Sasmita Bal, Purna Chandra Mishra and Ashok Kumar Satapathy – "Micro – Electro Discharge Machining of Holes and Grooves: An Assessment of Process Parameters" International Journal of Engineering and Technology (IJET), Vol. 9, Issue. 2, PP: 710 – 719, ISSN: 2319 – 8613, Apr – May 2017

B. Vinod Kumar." Optimization of Die-Sinking EDM Process Parameters with Steel Electrodes Using ANOVA." International Journal of Computational Engineering Research (IJCER), vol. 08, no. 06, 2018, pp. 60-66.