

# Study of the Effect of EDM Parameters based on Tool Overcut using Stainless Steel (SS 304 Grade)

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**Abstract**— The effect of process parameters on an EDM namely pulse on time ( $T_{ON}$ ), duty cycle (DC), discharge current (I) and gap voltage (V) were studied based on Tool Overcut (TOC). Taguchi's  $L_9$  orthogonal array was selected for conducting the experiments. Optimization was carried out using Signal to Noise ratios (SNR) and the main effects plot based on SNR. Duty cycle was found to be the most significant parameter that effected TOC followed by discharge current and pulse on time. Gap voltage had the least effect on TOC.

**Keywords**— Electrical Discharge Machining (EDM), Tool Overcut (TOC), Taguchi's Robust Design Technique, Signal to Noise ratio (SNR), ANOVA.

## I. INTRODUCTION

Electrical-discharge machining (EDM) is an unconventional, non-contact machining process where metal removal is based on thermo-electric principles. In this process, the material removal mechanism uses the electrical energy and turns it into thermal energy through a series of discrete electrical discharges occurring between the electrode and workpiece immersed in an insulating dielectric fluid [1]. Its unique feature of using thermal energy is to machine electrically conductive parts regardless of their hardness; its distinctive advantage is in the manufacture of mould, die, automotive, aerospace and other applications. Moreover, EDM does not make direct contact between the electrode and the workpiece, eliminating mechanical stresses, chatter and vibration problems during machining [2]. Hence, the tool material is generally softer than the workpiece material. EDM process is basically of two types:

- i. Die sinking EDM
- ii. Wire cut EDM

In case of die sinking EDM (or sinker EDM), a relatively soft graphite or metallic electrode can be used to cut hardened steel, or even carbide. The EDM process produces a cavity slightly larger than the electrode [3]. This excess dimension on the workpiece cut out by the tool during machining is called Tool Overcut (TOC). It is calculated as half the difference of the diameter of the hole produced on the workpiece to the tool diameter [4]. It is given by:

$$TOC = \frac{(D_0 - D_i)}{2}$$

where

$D_0$  is the diameter of the hole on the workpiece (mm) and  $D_i$  is the diameter of the tool (mm).

It is always desirable to achieve minimum TOC for better performance of the EDM process. An attempt has been made to minimize the TOC using Taguchi's Robust Design Technique based on certain independent cutting parameters. Taguchi's technique is a very useful tool for optimization of single response problems. In this technique, design of experiments is based on some orthogonal arrays founded by Dr. Taguchi called Taguchi's orthogonal arrays. It helps in reducing the number of experiments to be performed. After conducting the experiments, the signal to noise ratios are obtained using any if the three designs namely,

- (i) *Smaller the better* (for making the system response as small as possible)

$$SNR_S = -10 \log \left( \frac{1}{n} \sum_{i=1}^n y_i^2 \right)$$

- (ii) *Nominal the best* (for reducing variability around a target)

$$SNR_T = -10 \log \left( \frac{\bar{y}^2}{S^2} \right)$$

- (iii) *Larger the better* (for making the system response as large as possible)

$$SNR_L = -10 \log \left( \frac{1}{n} \sum_{i=1}^n \frac{1}{y_i^2} \right)$$

where,

$n$ =Number of trials/experiments

$y_i$ =Result of  $i^{\text{th}}$  experiment

$\bar{y}$ = Mean of the responses =  $\frac{1}{n} \sum_{i=1}^n y_i$

$$S = \text{Standard deviation} = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n-1}}$$

## II. LITERATURE REVIEW

Khanra et al. [5] attempted to develop a ZrB<sub>2</sub>-Cu composite that can be used as an EDM tool. They tested the tool by determination of responses like Material Removal Rate (MRR), Tool Removal Rate (TRR), Surface Roughness (SR) and TOC. They concluded that the overcut produced was higher in case of ZrB<sub>2</sub>-Cu composite compared to Cu tool. Nipanikar [6] optimized the process parameters of EDM by using Taguchi method. Optimization was carried out by taking into account the responses which include material removal rate MRR, EWR and TOC. He concluded that peak current had the maximum effect on ROC compared to other process parameters. Kubade and Jadhav [7] investigated the influence of EDM parameters on EWR, MRR and TOC while machining of AISI D3 material. They analyzed the result with the help of Taguchi's Orthogonal Array technique and concluded that peak current had maximum effect on TOC. Duty cycle and pulse on time also had considerable effect on TOC. Dhar and Purohit [8] evaluated the effect of discharge current, pulse on time and gap voltage on MRR, TWR and TOC on machining of Al-MMC with 20% SiC reinforcement. The analysis showed that an increase in discharge current and pulse on time increases TOC while gap voltage showed a reverse trend. Poddar [9] in his thesis studied the effects of different process parameters on an EDM based on MRR, SR and TOC. He concluded that the most significant factor was current followed by pulse on time and duty cycle respectively. TOC increased along with an increase in current. For increase in pulse on time, TOC increased linearly and for duty cycle, TOC increased initially and then started decreasing. Singh et al. [10] investigated the effect of TOC by varying certain cutting parameters on a rotary EDM during machining of Al/Al<sub>2</sub>O<sub>3</sub> composite. They conducted the experiments based on Taguchi's L27 orthogonal array. The signal-to-noise ratios were determined which indicated the optimum process parameters based on TOC. They concluded that TOC increased with an increase of discharge current, pulse on time and decrease in the value of pulse off time. Soni et al [11] proposed a technique to optimize EDM process based on Response Surface Methodology (RSM), Gray Relational Analysis (GRA) and Principal Component Analysis (PCA). They found that all the three input parameters namely discharge time, pulse current and duty cycle were significant factors for TOC under certain confidence level. Teimouri and Baseri [12] studied the effect of tool wear and TOC on an EDM using rotary tool and an external magnetic field. They came to the conclusion that application of magnetic field around the machining gap increased TOC while rotation of the tool had a negative effect on TOC.

## III. EXPERIMENTAL ANALYSIS

Experimental works have been undertaken for data collection on the Die Sinking EDM placed in the CNC Laboratory of Tool Room Training Centre, Amingaon.

The experiments were conducted on a die-sinking EDM. Its specifications are given in Table I. The workpiece material used was stainless steel (SS304). The tool material was copper. Straight polarity was used throughout the experiment. During experiment, there were some parameters which were kept constant throughout. These parameters with their values are given in Table II. The dimensions of the tool and electrode are given in Table III. The di-electric fluid used was SERVO oil (Grade 52).

TABLE I  
MACHINE SPECIFICATION OF THE EDM PROCESS

Particulars	Specification
Machine Model	ZNC 450
Machine Number	1104011
Manufacturer	J.K. Machines
Memory	100X40000 points
Data storage	60 sets

TABLE II  
CONSTANT OPERATING PARAMETERS USED DURING OPERATION IN EDM

Constant Parameters	Parameter values
High Volt	200V
Work Time	1 sec
Jump Length	0.8 m
Depth of cut	3 mm
Polarity	Straight (Electrode Negative)
Di-electric pressure	0.5 kg/cm <sup>2</sup>

TABLE III  
DIMENSIONS OF ELECTRODE AND TOOL

Dimensions	Stainless Steel (SS304)	Copper
Length (mm)	15	70
Diameter (mm)	16	3

Fig 1 shows the die-sinking EDM on which the experiments were conducted. This EDM is placed in the CNC laboratory of TRTC Guwahati.



Fig 1: Die-sinking EDM

The input parameters (four in number at three levels each) used to determine the responses are given in Table IV

TABLE IV  
INPUT PARAMETERS

Input variables	Unit	Symbol	Level		
			1	2	3
Pulse On Time	µs	T <sub>ON</sub>	200	500	800
Duty Cycle	%	DC	20	60	80
Discharge Current	Ampere	I	10	25	40
Gap Voltage	Volt	V	50	70	90

In this experiment the input parameters considered are Pulse On Time (T<sub>ON</sub>), Duty Cycle (DC), Discharge Current (I) and Gap Voltage (V). Since four factors are chosen with three levels each, Taguchi's L9 orthogonal array was selected for conducting the experiments. It is worthwhile to mention that no significant interaction effect was found among the factors as observed during initial set of experiments. The L9 orthogonal array is shown in Table V. The table contains the input parameters in coded form.

TABLE V  
L9 ORTHOGONAL ARRAY (REFER TO TABLE 4 FOR DATA)

Treatment Condition(TC)	T <sub>ON</sub>	DC	I	V
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The data obtained from experiments is shown in Table VI

TABLE VI  
RESPONSES OF EDM PROCESS

Treatment Condition:	TOC (mm)
1	0.305
2	0.31
3	0.385
4	0.435
5	0.315
6	0.42
7	0.34
8	0.185
9	0.43

IV. RESULTS AND DISCUSSION

The SNR of the data obtained in Table VI has been shown in Table VII. It is obtained using the 'Smaller the better' design as we require minimization of TOC. Next, a graph is plotted using MiniTAB with mean of SNR on the vertical axis and individual factor on the horizontal axis. This graph (main effects plot) shows the optimum level of the input parameters (Fig 2). As we require minimization of TOC, we select that particular level of a particular factor which is showing the minimum SNR. Combining the minimum values of SNR of each factor from the graph, the optimum cutting conditions are shown in Table VIII. At the optimum condition, the SNR is found out to be 16.5442

TABLE VII  
SNR VALUES

TC	Ton	DC	I	V	SNR
1	1	1	1	1	19.8564
2	1	2	2	2	19.7152
3	1	3	3	3	17.8332
4	2	1	2	3	16.7726
5	2	2	3	1	19.5762
6	2	3	1	2	17.0774
7	3	1	3	2	18.9128
8	3	2	1	3	24.199
9	3	3	2	1	16.8731

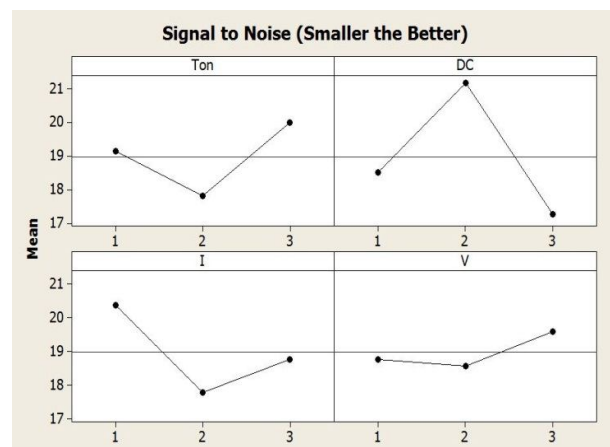


Fig 2: Main Effects Plot for TOC

TABLE VIII  
OPTIMUM CUTTING PARAMETERS

Input Parameter	Level
Pulse On Time	2
Duty Cycle	3
Discharge Current	2
Gap Voltage	2

Analysis of variance (ANOVA) is done which shows the percentage contribution of each factor on the responses and the significant factors. This is shown in Table IX.

TABLE IX  
ANOVA TABLE

Factor	DOF	SS	MSS	% Contribution	F ratio
T <sub>on</sub>	2	7.27	3.63	16.87	4.04
DC	2	23.81	11.90	55.19	13.22
I	2	10.25	5.12	23.77	5.69
V	2	*1.80	0.90	4.17	--
Error	0	0	--	--	
Total	8	43.15	--	100	
Error	(2)	(1.80)	(0.90)		

\*Indicates sum of squares added together with the error sum of squares to estimate the pooled error sum of squares shown within parenthesis. F ratio is calculated as the ratio of factor mean square to the error mean square

where,

SS indicates Sum of squares and MSS indicates Mean sum of squares.

### CONCLUSION

In the present work, the optimal cutting parameters of a die sinking EDM process based on Tool Overcut was determined. It was observed that TOC decreases initially and then increases with a gradual increase in pulse on time. Duty cycle causes an increase in TOC initially but decreases afterwards. From the ANOVA table, it is seen that duty cycle (DC) had the highest contribution (55.19%) among all the factors followed by discharge current (I) and pulse on time (T<sub>ON</sub>) while gap voltage (V) had the least effect. At 90% confidence level, it was observed that duty cycle was also the most significant while all other factors were insignificant.

### REFERENCES

- [1] Srivastava V., Pandey P.M., "Effect of process parameters on the performance of EDM process with ultrasonic assisted cryogenically cooled electrode", Journal of Manufacturing Processes, Vol. 14, Pg. 393–402, 2012.
- [2] Rajesh R., Anand M.D., "The Optimization of the Electro-Discharge Machining Process Using Response Surface Methodology and Genetic Algorithms", International Conference on Modelling, Optimization and Computing (ICMOC - 2012), Procedia Engineering, Vol. 38, Pg. 3941 – 3950, 2012.
- [3] Krar S., "Electrical Discharge Machining (Cutting Metal to Precise Shapes using Electricity)" Article (URL: www.automationmag.com/images/.../91%20Electrical%20Discharge.pdf)
- [4] Poddar A., "Experimental Investigation of MRR, Surface Roughness and Overcut of AISI 304 Stainless Steel in EDM", B.Tech Thesis, NIT Rourkela, 2012.
- [5] Khanra A K, Pathak L C and Godkhindi M M, "Application of new tool material for electrical discharge machining (EDM)", Bull. Mater. Sci., Indian Academy of Sciences Vol. 32, No. 4, Pg. 401–405, 2009.
- [6] Nipanikar, "Parameter Optimization of Electro Discharge Machining of AISI D3 Steel Material by using Taguchi Method", Journal of Engineering Research and Studies, Vol. 3, No. 3, Pg. 7-10, 2012.
- [7] Kubade P.R., Jadhav V.S., "An Experimental Investigation of Electrode Wear Rate (EWR), Material Removal Rate (MRR) and Radial Overcut (ROC) in EDM of High Carbon-High Chromium Steel (AISI D3)", International Journal of Engineering and Advanced Technology (IJEAT), Vol. 1, No. 5, Pg. 135-140, 2012.
- [8] Dhar S., Purohit R., "Mathematical Modeling and Statistical Analysis for Electric Discharge Machining (EDM) of Al-20% SI-CP cast metal matrix composite", 2nd International Conference on Recent Advances in Composite Materials, IT-BHU, Varanasi, India, 2006.
- [9] Poddar A., "Experimental Investigation of MRR, Surface Roughness and Overcut of AISI 304 Stainless Steel in EDM", B.Tech Thesis, NIT Rourkela, 2012.
- [10] Singh M.P., Kalra C.S., Singh S., "An Experimental Investigation of Radial Overcut during Machining of Al/Al<sub>2</sub>O<sub>3</sub> MMC by Rotary EDM", International Journal of Emerging Technology and Advanced Engineering, Vol. 3, No. 4, Pg. 617-619, 2013.
- [11] Soni H., Mishra T.K., Pradhan M.K., "Multi-Response Optimization of EDM Parameters by Grey-PCA Method", International Journal of Current Engineering and Technology, Vol. 3, No. 5, Pg 1941-1945, 2013.
- [12] Teimouri R., Baseri H., "Study of Tool Wear and Overcut in EDM Process with Rotary Tool and Magnetic Field", Research Article, Hindawi Publishing Corporation, Advances in Tribology, Vol 2012, Pg. 1-8, 2012.