Optimization of Process Parameters in Electrical Discharge Machining of EN 8 Steel by Using Taguchi Technique

L. Feroz Ali, N. Kuppuswamy, Babu Narayanan, Sree Hari, Swasthik Vellingiri

***Abstract*: This current work aims at determination of the best process parameter in electric discharge machining (EDM) of EN 8 alloy steel using Taguchi Technique. Experimental study was carried out as per L_9 orthogonal array of design of experiment with an intention of saving time and reduction of the experimental runs. Since this study involves the multiple-characteristics results such as material removal rate (MRR), electrode wear rate (EWR) and surface roughness. Results of Analysis of variance (ANOVA) reveal that MRR and EWR have significantly improved. Eventually authentication test was being done for better understanding the effectiveness of this planned method.**

***Keywords*: Material removal rate, Electrode Wear Rate, Surface roughness, EN 8 Alloy Steel, Taguchi, Optimization, EDM.**

I. INTRODUCTION

EN8 metal with its various types of alloys are being used in industries since it has lofty strength and good thermal resistivity and better mechanical properties at peak and low temperatures. The main outcome of this work is to find out the best levels to achieve improved metallurgical properties and at optimized process parameter levels. The paper by Senkathir [1] influences on the EDM machining by using Inconel 718 shows the reduction of machining time, circularity error and surface roughness. The paper by Suthan [2] demonstrates the machining by using wire EDM for SS316L using Taguchi's orthogonal array for improving the output level machining and optimum response and surface roughness. The paper by Malak Soni [3] and Anjaneya Acharya describes the machining of EN8 alloy steel by using Taguchi's L9 orthogonal array with a special rotary arrangement for machining solid or tubular electrodes and decrease of the tool wear rate (TWR) and optimum machining parameters. The paper by Suryawanshi [4] describes the special arrangement of a function generator and AISI D3 steel as a tool for EN24 alloy to find the optimum parameters by using an artificial neural network (ANN) model. The paper by Pradeep Singh [5] describes the EN8 alloy machining using Taguchi's L18 orthogonal array and finding the optimum parameters by using Minitab software
and using a mathematical formula. The paper by Kishan [6] describes the development of a mathematical model for EDM machining by using copper and brass electrodes with 5% level of significance by using analysis of variance. The paper by Anjaneya Acharya [7] describes the machining and achieving the best parameters with and without heat treatment of the EN8 alloy steel. The paper by Jeevanantham [8] describes the surface grinding of EN8 and EN31 alloys to achieve the best surface roughness. The paper by Chinmaya.P.Mohanty [9] describes the creation of a thermal based model using finite element method by using regression analysis.

II. MATERIALS AND METHODS

Work-piece material opted for the current investigation is EN 8 [7, 8, 9] alloy steel having the chemical composition as shown in Table 1. A cylindrical work-piece of dimension of 15mm diameter and 20 mm length is being used here. Electrode material chosen was Copper of diameter 15mm. Experimental work is being accomplished on an Electronica M2SEDM machine. The experimental setup along with work piece profile is diplayed in the Fig. 1 (a) and (b)

Fig. 1 (a) Electric Discharge Machine Setup

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(b) Workpiece Sample

Table 1 Chemical composition of 080M40(EN8)

Sl. No	MATERIALS	CONTENTS
1	Carbon	0.36-0.44%
2	Silicon	0.10-0.40%
3	Manganese	0.60-1.00%
4	Sulphur	0.050 Max
5	Phosphorus	0.050 Max
6	Chromium	0.050 Max
7	Molybdenum	0.025 Max
8	Nickel	0.65-1.00%

III. DESIGN OF EXPERIMENTS

The process variables effects on the electric discharge machining is being investigated with the help of Taguchi's technique. It is a smooth and powerful tool used for quality optimization of process variables while machining. After conducting the pilot test, it was decided to select the levels of experiments. For the present case, input parameters considered are pulse on time, pulse off time and current at three levels. The detail of process variable and their levels are shown in Table 2. Samples were machined in accordance to aforesaid experimental design and responses were measured as indicated in Table 3. Samples after EDM process is shown in the Fig. 2.

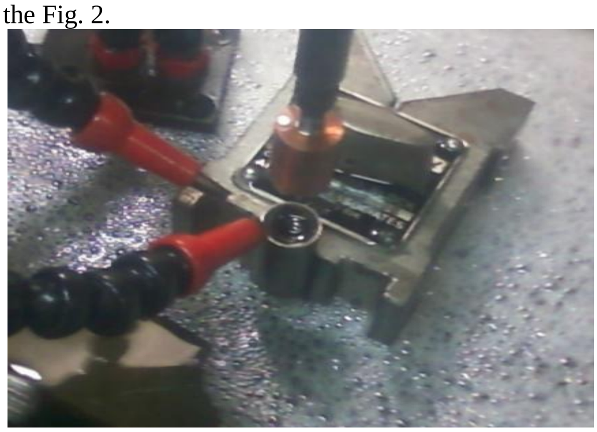

Fig. 2 (a) Machining Set Up

(b) Sample Specimen

Table 2 Control Variables and Their Levels

Expt. No	LEVELS		
	1	2	3
A. Current (A)	a	b	c
B. ON Time(s)	d	e	f
C. OFF Time(s)	g	h	i

A detailed study on the input parameters with respect to the response variables like MRR and EWR was observed. Several experiments were conducted and the average of three values has been examined for the eventual output of each response. With the support of L_9 Taguchi's orthogonal array, the number of factors and their levels were chosen and it is displayed in Table 3 below.

On the off chance that a capacity has be to standardized, at that point Taguchi's procedure yields great outcomes. "Motion to-clamor (S/N) proportion" will diminish the variety in the yield reactions that is being gotten from the test yield information by recognizing the characteristics as "higher the better (HB), bring down the better (LB), and ostensible the best (NB). The conditions showed underneath are utilized to figure the sort of finishing trademark utilizing S/N proportion:

$$HB: Signal\ to\ Ratio\ (S/N) = -10\log_{10}\left[\frac{1}{m}\sum_{i=1}^{m} X^{-2}\right] \text{.....................(1)}$$

$$LB: Signal\ to\ Ratio\ (S/N) = -10\log_{10}\left[\frac{1}{m}\sum_{i=1}^{m} X^{2}\right] \text{........................(2)}$$

Where, X *is* the sample mean for the number of examinations in each trial by contract.

Using the below expressions the material removal rate and electrode wear rate were calculated

Electrode Wear Rate = Weight of electrode or tool removed/Time (g/min).

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Material Removal Rate = Weight of material removed / Time (g/min).

R_a indicates the surface roughness, which is being measured using the surface roughness.

Table 3 Experimental layout using L_9orthogonal array with factors and responses

Expt. No	FACTORS		
	A	**B**	**C**
1	5	7	3
2	5	6	4
3	5	5	5
4	7.5	7	5
5	7.5	6	4
6	7.5	5	3
7	10	7	5
8	10	6	3
9	10	5	4

Table 4 Experimental Layout Using L_9 Orthogonal Array with Factors and Responses

Sl. No	Initial Weight of work piece	Final Weight of work piece	Initial Weight of Electrode	Final Weight of Electrode	Time (min)	MRR (g/min)	EWR (g/min)
1	**41.218**	**38.684**	**38.232**	**38.218**	**56**	**.0452**	**.00025**
2	41.268	38.710	38.537	38.430	45	.0568	.0023
3	41.424	39.054	40.211	40.188	39	.0602	.00058
4	**41.460**	**39.268**	**40.211**	**40.188**	**32**	**.0685**	**.00017**
5	41.068	39.181	38.322	38.306	33	.0571	.00048
6	41.725	39.665	39.154	39.138	26	.0792	.00061
7	**41.088**	**39.318**	**38.209**	**38.185**	**10**	**.1775**	**.0024**
8	41.243	38.613	39.975	39.946	19	.1382	.00152
9	41.598	37.843	39.842	39.795	20	.1875	.00235

The table 4 above shows the machining time and the electrode wear rate, material removal rate, electrode wear rate and the early and end weight of the work piece. From this table the best optimal parameters are obtained.

IV. RESULTS AND DISCUSSION

Material Removal Rate

By the thought of material evacuation rate the productivity of the procedure can be resolved. The MRR is seen as the volumetric material evacuated every moment amid machining. Greatest estimation of MRR shows the quicker creation rate, which is truly necessary right now in the ventures. A higher MRR is attractive for EDM process. Because of the climb in pinnacle present and diminishing of heartbeat off time, the vitality of material evacuation increments, alongside upgrade in the release recurrence [18]. The release vitality centralization of the flash hole ventures up the liquescent and vaporization of liquid metal and coasting metal hanging in the EDM which prompts increment of MRR. [16,17].

The present work uncovered that higher MRR can be accomplished at the lower sparkle gap voltage and heartbeat off time combined with higher pinnacle current..

Surface Roughness

R_a indicates the surface roughness, which is being measured using the surface roughness. It is observed that the increase in peak current results hike in surface roughness. As the discharge points in the cutting zone increases due to the increase in pulse discharge energy. As the discharge energy increases, large amount of material is removed from the work piece. It tends to the generation of cavities on the outward area, which in turn increases the surface roughness. Meanwhile, when we increase the feed rate the surface roughness is getting decreased. The spark produced between the tool and the work piece is stable, thereby generating constant discharge conditions which resulted in lower surface roughness.

SEM Analysis

For knowing the spatial variations along with chemical characteristics, we have gone for scanning electron microscopy analysis, because of its wide spectrum of applications. Here we have collected the data over a selected area of the surface of the sample and we studied its surface, texture and orientation of materials over the area. We got the analysis of the selected point locations on the sample. By this we had the capacity to calculate out the subjective or semi-quantitative assurance of the synthetic syntheses, crystalline structure and crystal stone orientations.

Sample 1 (a) Afore machining

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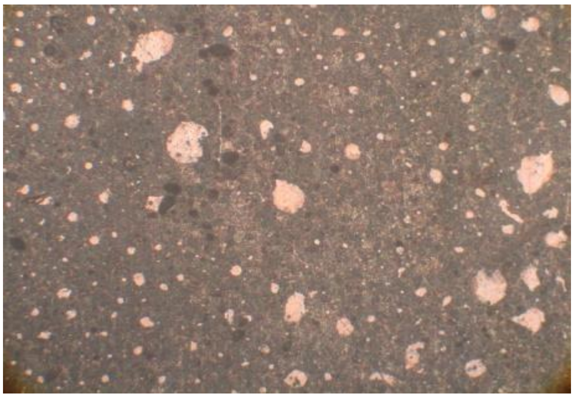
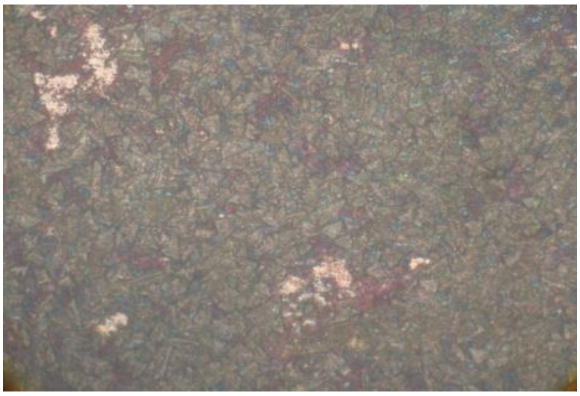
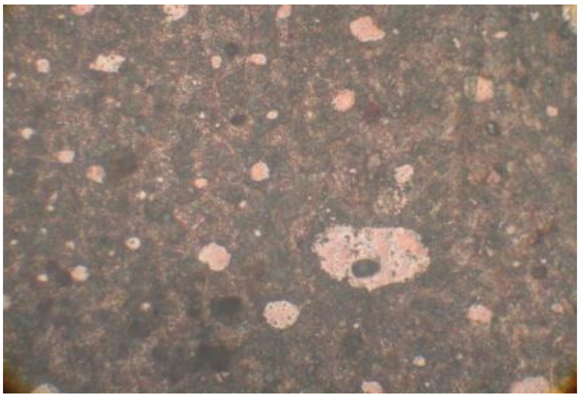


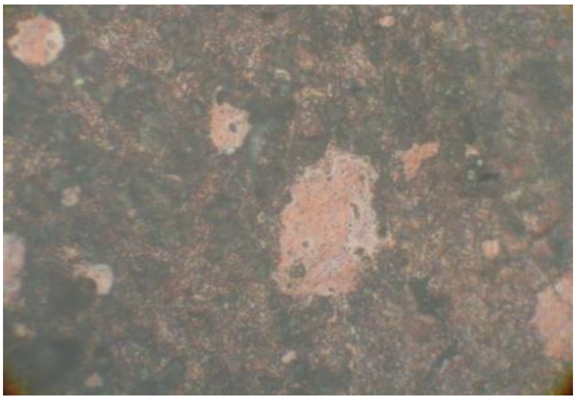
(b) Later Machining



Sample 4 (a) Afore machining



(b)Later Machining



Sample 7 (a) Afore machining

(b) Later Machining

Figure 3 SEM Images of Machined Surfaces

V. CONCLUSION

Better surface is obtained and surface roughness is greatly reduced as shown in the figure above and the Tool Wear Rate (TWR) is considerably decreased after the experimentation process of first trail (0.00025). Material Removal Rate (MRR) is greatly increased during the 9^{th} trail (20 minutes). From confirmation test it has been observed that the experimental values give better result as compare to predicted values. Thus we conclude that the Taguchi Method is best procedure for better arrangement of single target improvement process.

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