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Optimization of Electrical Discharge Machining Parameters For EN-24 Low Alloy Steel

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Abstract

Electric Discharge machining is used to pro-duce complex shapes that would be difficult to produce in conventional machine tools and also good surface finish can be obtained in EDM. The work material EN24 is machined by using copper as electrode. The EN24 contains nickel, chromium and molybdenum and it is used in automobile and aircraft transmission components .For this reason, the EN24 is experimentally investigated with the machining parameters for achieving maximum MRR and minimum and surface roughness.[1] The ANOVA is also used to identify the ma-chining parameter responses on MRR and SR. The input parameters are peak current, pulse on time, discharge voltage and pulse off time. Regression equations are formulated based on the experimental results. The effects of input parameters are analyzed on MRR and SR.

Key Words- *EDM, EN-24, ANOVA, MRR, SR*

I. INTRODUCTION

In EDM work piece. It is immersed in dielectric fluid and the pulse generator creates electric spark between the work piece and electrode tool due to this ma-terial is removed from workpiece.

Heat resistant steels, super alloys, car-bides, heat treated tool steels, composites and ceramics which are difficult to machine can be machined to attain geo-metrically complex shape in EDM for which the process parameters must be optimized. [2]

Optimum process parameters are to be followed while machining in EDM to obtain maximum Material Removal Rate (MRR) and minimum Surface Roughness (SR).

In the heat treated condition EN24 is capable of developing high strength. Its toughness and retaining good fatigue strength is commendable.

Previously few researchers have considered optimizing material removal rate, tool wear and overcut with Taguchi methodology but not surface roughness. So this work considers MRR and surface roughness.

We have studied the modeling of the EDM process for the purpose of providing minimum cost and maximum production rate. They used the Analysis of Variance methodology to establish mathematical relations between the principal process parameters and response parameters such as material removal rate; percentage electrode wear and surface finish of electrical discharge machined surfaces.

II. Methodology

Experimental investigation is done through design of experiments and the parameter influence and interaction effect on peak current, pulse on time and pulse off time and gape voltage are examined.

III. Work Piece and Electrode Material

EN 24 is the work material which is a low alloy medium carbon steel used for large size parts which requires high strength and toughness. The electrode material is copper.

IV. Characteristics

This nickel-chromium-molybdenum alloy possesses increased ductility and toughness and much deeper harden ability. EN 24 is ideal for all highly stressed parts in the most severe conditions because of its high fatigue strength. It has good wear resistance and used in both elevated and low temperature environments. Typical applications include aircraft landing gear, power transmission gears and shafts and other structural parts, high strength machine parts, heavy-duty shafting, high tensile bolts and studs, gears, axle shafts, crankshafts, boring bars and down-hole drilling components.

V. Experimental Setup

A25 Electric Discharge machine manufactured by Tool Craft Spark Generator make is the machine used to carry out this experiment. The input parameters considered for process optimization are Ton, Pulse on time, Ip,Peak current Toff, Pulse off time and Dicscharge Voltage. Weight of work piece and electrode is measured using electronic weighing scale before and after machining to measure material removal rate and electrode wear rate. Mathematical models are developed on the basis of experimental data. The table 1 shows the EDM input parameters and their levels.

Table 1: Input parameters and their level

Input Parameters	**Unit**	**Symbol**	**Range**	**Level 1**	**Level 2**	**Level 3**
T_{ON}	**µs**	B	0.25-4000			
I_D	A	C	0.5-50			
T_{OFF}	**µs**	D	0.25-4000			
				Level 1	**Level 2**	
Gape Voltage	V	A	1-150	50	90	

The die electric used is clean kerosene. Through pressure flushing kerosene under pressure of 0.80 kg/cm2 is admitted in the vicinity of the spark area and the debris is carried away. The response surface methodology is analyzed to maximize MRR and to minimize SR.

VI. Measurement Procedure

An electronic weighing scale is used to measure the weight of work piece before and after trial. The digital timer is used to measure the period of trial in minutes. SURFCORDER, a surface roughness measuring instrument is used to measure the surface roughness Ra in terms of µM.

VII. Measurement of MRR

$$MRR = \frac{(Wi - Wf)x1000}{7.8xt}\ mm3/_{min}$$

Where Wi = weight of work piece in grams before trial
Wf= weight of work piece in grams after trial
t = period of trial in minutes
7.8= Density of steel in gms/cc

VIII. Mathematical Modeling

Mathematical models are developed on the basis of experimental data. The experimental planning is done based on Design of Experiments.

Design of Experiments (DOE) is a method used to obtain useful information about a process by conducting only minimum number of experiments. Each controllable variable (Ton, Ip, Toff) can be set on EDM machine at three consecutive levels and hence the design consisting of 18 experiments based as shown in fig

IX. Experimental Results

Table 2: Experimental Results

Exp No.	Gape Voltage	T_{ON}	I_D	T_{OFF}	MRR	SR
1	50	50	3	5	8.5128	3.8
2	50	50	9	10	29.8717	7.4
3	50	50	12	20	62.7025	7.8
4	50	100	3	5	3.2820	7.13
5	50	100	9	10	49.4102	8.26
6	50	100	12	20	22.9487	12.67
7	50	150	3	10	4.6320	6.13
8	50	150	9	20	29.5000	7.33
9	50	150	12	5	52.2000	12.67
10	100	50	3	20	3.2910	3.8
11	100	50	9	5	19.9102	7.4
12	100	50	12	10	19.1538	8.1
13	100	100	3	10	18.9743	7.72
14	100	100	9	20	4.31025	8.2
15	100	100	12	5	53.6102	8.6
16	100	150	3	20	3.1192	6.13
17	100	150	9	5	19.1423	8.4
18	100	150	12	10	53.9923	12.84

X. Analysis of Experimental Results

Material Removal Rate (MRR)-

Table 2 shows the orthogonal array based experimental results of MRR, whose ANOVA results are shown in Table 3. Observation of Table 3 indicates that discharge current is the most dominant factor having percentage contribution as 59.76%, followed by gap voltage and pulse-on-time. Figure shows that MRR increases with the increase in discharge current. Higher discharge current induces more spark energy which causes larger overcuts and thus removes more material [4]. Figure shows that MRR increases as the value of pulse-on-time increases. Higher pulse-on-time, i.e. spark energy for a longer time, results in larger craters on work piece and thus increases MRR. It is observed that MRR is maximum for a certain value of pulse-on-time and further increment in pulse-on-time is less affect MRR considerably. Increment in gap voltage increases the discharge gap distance which, in effect, reduces the effect of induced energy at work piece and hence MRR decreases [5].

Table 3: Analysis of Variance for MRR

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	Percentage contribution
Gape Voltage(A)	1	100.7	100.7	0.40	1.26%
Pulse-on time (B)	2	210.9	105.4	0.42	2.64%
Discharge current(C)	2	4767.6	2383.8	9.41	59.76%
Pulse off time (D)	2	366.2	183.1	0.72	4.59%
Error	10	2532.2	253.2		
Total	17	7977.5			

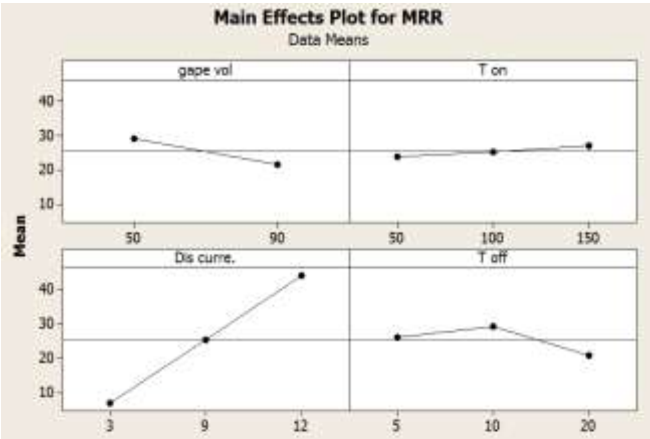

Figure 1: Main Effect plot for MRR

Surface Roughness (SR) –

OA based experimental results of SR are reported in table 2. ANOVA results for SR, as reported in Table 4, indicate that discharge current is the most dominant factor having percentage contribution as 58.68, followed by pulse-on-time and shape factor. Figure shows that SR increases when discharge current and pulse-on time increase. The electric-discharge machined surface consists of a multitude of overlapping craters that are formed by spark discharges [6]. The size of these craters depends on the discharge energy and duration. More is the discharge energy (i.e. discharge current) and duration (i.e. pulse-on-time), the larger is the size of craters resulting in more surface roughness. [7]

Table 4 Analysis of Variance for SR

Source	**Degrees of freedom**	**Sum of squares**	**Mean square**	**F-ratio**	**Percentage contribution**
Gape Voltage(A)	**1**	**0.294**	**0.294**	**0.15**	**0.26%**
Pulse-on time (B)	**2**	**23.684**	**11.842**	**6.03**	**21.59%**
Discharge current(C)	**2**	**64.071**	**32.036**	**16.30**	**58.68%**
Pulse of time (D)	**2**	**1.484**	**0.742**	**0.38**	**1.35%**
Error	**10**	**19.651**	**1.965**		
Total	**17**	**109.185**			

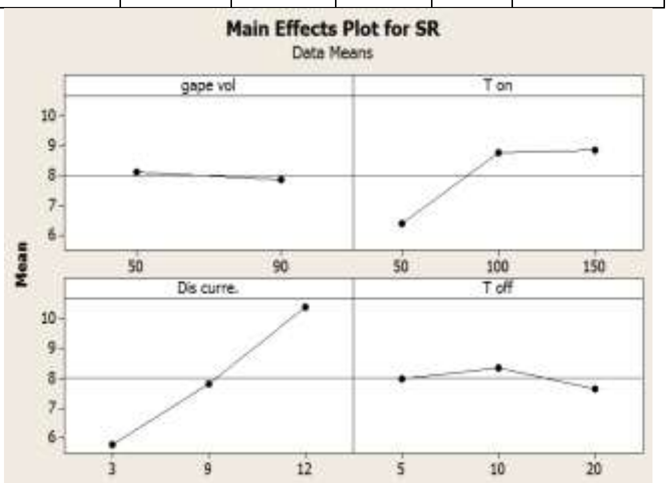

Figure 2: Main Effects Plot for SR

XI. Results

Table 5 Mean S/N ratio for MRR

Parameters	**Level 1**	**Level 2**	**Level 3**	**selected level**	**Optimum level**
A-Gape voltage	26.92	25.03		A1	A1B3C3D2
B-Pulse on time	24.58	25.94	27.41	B3	
C-Discharge current	17.16	27.64	33.14	C3	
D-Pulse off time	26.29	28.87	22.77	D2	

Table 6 Mean S/N ratio for SR

Parameters	**Level 1**	**Level 2**	**Level 3**	**selected level**	**Optimum level**
A-Gape voltage	17.71	17.56		A1	A1B2C3D2
B-Pulse on time	15.66	18.70	18.55	B2	
C-Discharge current	14.92	17.86	20.13	C3	
D-Pulse off time	17.55	18.23	17.14	D2	

XII. Conclusion

Taguchi's method has been employed to obtain the optimal factor/level combination of process parameters for MRR. This approach is found as simple, effective and efficient single-objective optimization technique. A1B3C3D2, A1B2C3D2 are recommended as optimum factor/level combination for MRR and SR respectively.

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