EDM Process Parameter Optimization with Copper Electrode using Taguchi Method

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Abstract - The experiment for optimization of EDM process parameter is performed on AISI D3 tool steel using copper electrode of 10 mm diameter in this paper. The process parameters are decided based on the Taguchi method. The aim of this work is to make advance process parameters of machining in high, medium and low wear factors which are 2, 4 and 6 through duty cycle 40%, 50% and 60% respectively. During whole process the process parameters are kept constant. The MRR and EWR also analyzed in this experiment.

Keywords: Copper Electrode, EDM Process Parameters, Taguchi Method.

I. INTRODUCTION

In view of development in electric discharge machining (EDM) procedure performance, advancement of process parameters consideration is noteworthy. EDM procedure performance MRR, SF and TWR can be enhanced extensively by opting better combination of input parameters. EDM is able to make composite cuts on tricky-to-cut equipment. The upper degree of correctness and superior surface class irrespective of the stiffness of the job material build this procedure valuable. The variety of constructive machining situation is one of the most significant aspects of EDM procedure owing to the normally lower material exclusion rates. Whenever sparking takes place between two electrical contacts a small amount of material is removed from each of the contacts. This fact was realized and the attempts were made to harness and control the spark energy to employ it for the useful purpose, say for machining of metals. It was found that spark of short duration and high frequency is needed for efficient machining. Further, it was also observed that if the discharge is submerged in dielectric, the energy can be concentrated into a small area.

II. LITERATURE SURVEY

Y. H. Guu has done the experiment on machining of AISI D2 tool steel using EDM. From his experiments it comes to know that higher discharge energy results in a poorer surface structure. To avoid excessive machined damage, low discharge energy should be used. [1]

Prabhu and B.K. Vinayagam have done the experiment on Machining of AISI D2 tool steel using EDM with single wall carbon nano tube. He found that excellent machined finish is obtained by setting the machine parameters at a low pulse energy. The specimens sparked using Carbon Nano Tubes have better surface finish. [4]

R.A. Mahdavinejad optimized the process parameter Machining of AISI D3tool steel from predictive controller model based on neural network using EDM. He investigated that capability of the system of predictive controller model based on neural network works with 32.8% efficiency increasing in stock removal rate. [3]

In studying Effect of Copper Electrode Material on EDM of AISI D2 Tool Steel using EDM with copper electrode S. Prabhu found that the most dominant parameter on the surface roughness was pulse current, while the second ranking factor was pulse on duration[7].

III. WORKING PRINCIPLE OF EDM

EDM is a thermo electric process in which heat energy of spark is used to remove the material from the work piece. The work piece and tool should be made of electrically conductive materials. A spark is produced between two electrodes (tool and work piece) and its location is determined by the narrowest gap between the two. Duration of each spark is very short. The entire cycle time is a few micro-seconds. The frequency of sparking may be as high as thousands of sparks per second. The area over which a spark is effective is also very small. However, temperature of the area under the spark is very high. As a result, the spark energy is capable of partly melting and partly vaporizing material from localized area on both the electrodes. The material is removed in the form of craters which spread over the entire surface of the work piece. Finally the cavity is produced in the work piece is approximately the replica of the tool. To have machined cavity as replica of the tool, tool wear should be zero. To minimize wear of the tool the operating parameters and polarity should be selected carefully.

Particles eroded from the electrodes are known as debris. Usually the amount of material eroded from the tool surface is much smaller than that from the work piece surface. A very small gap between the two electrodes is to be maintained to have the spark to occur. For this purpose, a tool driven by the servo system is continuously moved towards the work piece.

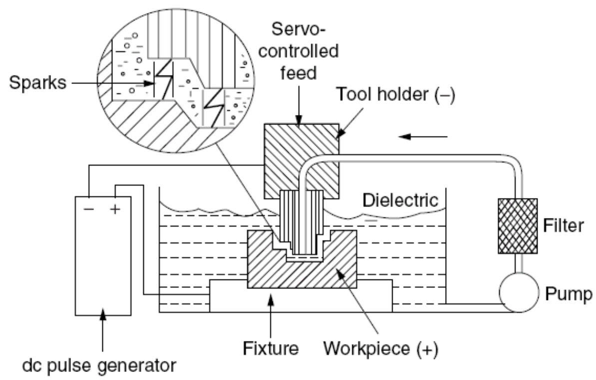

Fig 1: Working principle of EDM

During EDM, pulsed DC of 80-100 V at approximately 5 kHz is passed through the electrodes. It results in intense electric field at location where surface irregularity provides the narrowest gap. Negatively charged particles (electrons) break loose from the cathode surface and move towards the anode surface under the influence of the electric field forces.

IV. MATERIAL PROPERTIES

A. *Work piece Properties*

AISI D3 tool steel contains the alloying element as per table given below:

TABLE 1. ALLOYING ELEMENT IN AISI D3 TOOL STEEL

Element	**C**	**S**	**P**	**Mn**
%	2.02	0.026	0.028	0.59
Element	**Si**	**Cr**	**V**	**W**
%	0.28	11.14	0.021	0.07

From the above effects of different alloying elements we can conclude that Hardness of such material is very high. So it is very difficult task to machine it with ordinary machining process

B. *Electrode (Tool) Properties*

In this experiment the copper is selected as a tool material with the properties listed in Table 2.

TABLE 2.MECHANICAL AND THERMAL PROPERTIES OF COPPER TOOL

Density	8.9 g/cm^3
Melting Point	1083 °C
Electrical Resistivity	1.96micro-Ohm/cm
Electrical conductivity	92%
Thermal Conductivity	380.7 W/mK
Specific Heat	0.092 cal/g°C
Coefficient of thermal Expansion	6.6X10^{-6}C^{-1}

V. EXPERIMENTAL DATA

The machining parameters chosen for the present experiment are current, open-circuit voltage and duty cycle. Pulse-on time (t_d) is the duration of time (in μs) the current is allowed to flow per cycle. Pulse-off time (t_o) be the duration of time (in μs) between two consecutive sparks. On the other hand, duty cycle (D) is the ratio of the pulse-on time to the total pulse time expressed in percentage. Hence it can be expressed mathematically as

Duty cycle = (On time * 100)/ (On time + off time)

The machining parameters and their levels are presented in Table 3. For coding the values of the duty cycle in the levels of -1, 0, 1 pulse-on time was changed i.e., 20, 30 and 40 μs by keeping the duty cycle of 40%, 50% and 60%.

TABLE 3. THE MACHINING PARAMETERS AND THEIR LEVELS

Current	2	4	6
Duty cycle	40%	50%	60%
On time	20	30	40

Work piece was cut in the form of 50mm * 50mm * 10mm. Subsequently nominal cut on lathe was carried out to remove rust and corrosion. After machining it was thoroughly cleaned with Acid to remove the carbon deposition, and the weight measurements were taken on electronic weighing machine, which has a resolution of 0.001 grams. Each experiment was carried out and weight loss of material and electrode are measured.

Initial weights of the work piece and copper electrodes are given in the Table 4.

TABLE 4. INITIALS WEIGHTS OF WORK PIECES AND ELECTRODES

No.	Work piece(gm)	Copper (gm)
1	187.701	33.829
2	188.317	32.956

3	177.565	34.635
4	182.091	31.351
5	177.933	33.576
6	188.900	33.324

MRR (Material removal rate) = Difference in Weight of work piece before and after machining/ Time of machining

EWR (Electrode wear rate) = Difference in Weight of electrode before and after machining/ Time of machining.

VI. EXPERIMENTAL PROCEDURE

During the experiment we have taken total 27 readings on the copper electrode. Time taken for machining was recorded by digital stop watch and then weight loss of work piece and electrode are calculated. From the equations given in above chapter electrode wear rate (EWR) and material removal rate (MRR) are measured which is given in the table described below. Other working parameters are kept constant which are given below.

TABLE 5. PROCESS PARAMETERS (CONSTANT DURING EXPERIMENT)

Voltage	4	Working Time	6
Sparking gap	5	Flushing Speed	1
Servo Sensitivity	6	Arc Sensitivity	1
Flushing Height	13	Low wear factor	0
Electrode polarity	1		

TABLE 6. OBSERVATION TABLE

Peak Current (A)	ON Time (μs)	Duty Cycle (%)	Machining Time (min)	Weight Lost(W)(gm)	Weight Lost (E)(gm)	MRR (mm^3/min)	EWR (mm^3/min)
2	20	40	20.3	0.059	0.002	0.3265618	0.01106991
2	20	60	19.55	0.061	0.002	0.35058427	0.011494607
2	20	80	19.09	0.068	0.001	0.40023258	0.005885775
2	30	40	52.19	0.067	0.001	0.14424382	0.002152899
2	30	60	10.29	0.033	0.001	0.36033708	0.010919292
2	30	80	9.5	0.058	0.001	0.68598427	0.011827303
2	40	40	58.32	0.058	0.001	0.1117427	0.001926607
2	40	60	22.49	0.054	0.001	0.26978315	0.004995978
2	40	80	22.14	0.083	0.001	0.42122135	0.005074955
4	20	40	13.59	0.075	0.002	0.62008539	0.016535618
4	20	60	6.31	0.055	0.001	0.9793618	0.017806629
4	20	80	7.56	0.073	0.001	1.08495281	0.01486236
4	30	40	10.1	0.062	0.001	0.68973146	0.011124708
4	30	60	5.54	0.064	0.000	1.29801685	0.000000000
4	30	80	5.18	0.054	0.001	1.17131573	0.021691011
4	40	40	24.18	0.08	0.000	0.37174382	0.00000000
4	40	60	9.01	0.081	0.001	1.01011348	0.012470562
4	40	80	6.01	0.071	0.001	1.32737528	0.018695393
6	20	40	7.38	0.112	0.002	1.70518539	0.030449775
6	20	60	2.35	0.068	0.003	3.25125506	0.143437753
6	20	80	3.15	0.079	0.000	2.81790674	0.000000000
6	30	40	5.25	0.074	0.001	1.58373483	0.021401798
6	30	60	2.45	0.072	0.001	3.30199551	0.045861011
6	30	80	2.02	0.082	0.001	4.56113034	0.055623596
6	40	40	7.38	0.067	0.001	1.02006629	0.015224831
6	40	60	3.13	0.091	0.001	3.26668315	0.03589764
6	40	80	2.08	0.102	0.001	5.50993933	0.054018989

VII. Result and Discussion for MRR

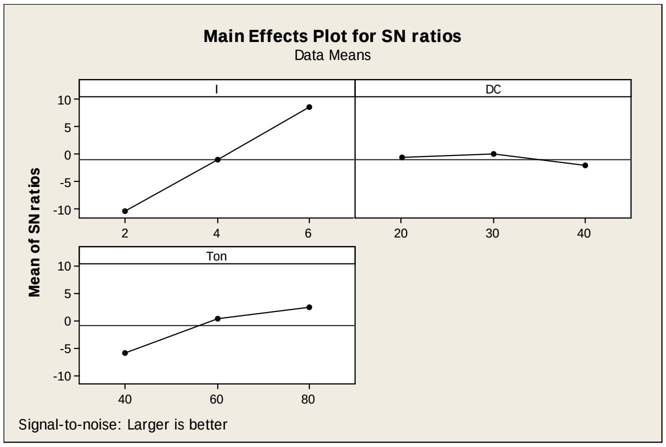

Fig 2. Main effect plot for SN Ratio (MRR)

Fig 2 shows that the material removal rate increases with the increase of pulse on time and peak current and almost constant with increase in duty cycle. This is because the discharge energy increases with the pulse on time and peak current leading to a faster cutting rate ultimately material removal rate. As the duty cycle (pulse off time) decreases, the number of discharges within a given period becomes more which leads to a higher cutting rate. It is also evident that MRR is minimum at first level of peak current and pulse on time and maximum at last level of peak current and pulse on time.

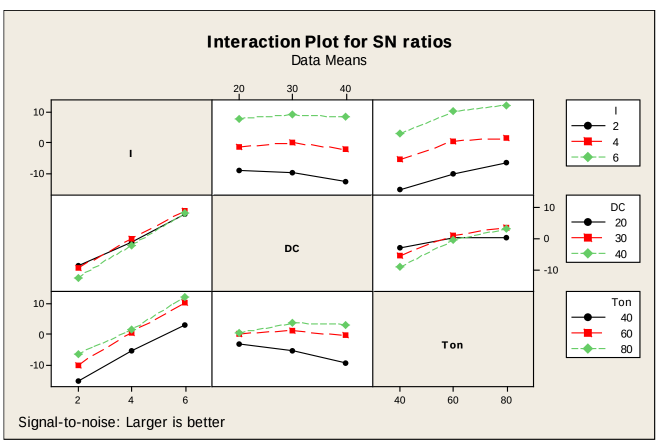

Fig 3. Interection plot for SN Ratio

It is seen from the Figure 5.12 that there is very weak interaction between peak current with the duty cycle and pulse on time in affecting the material removal rate since the responses at different levels of process parameters for a given level of parameter value are almost parallel. However, the good interaction of pulse on time and the duty cycle is seen.

Table 6. Response Table for MRR (S/N Data)

Level	I	DC	Ton
1	-10.41	-0.725	-5.861
2	-1.029	-0.111	0.4134
3	8.5226	-2.077	2.5341
Delta	18.929	1.9668	8.3947
Rank	1	3	2

Table 6 includes ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor.

VIII. Result and Discussion for EWR

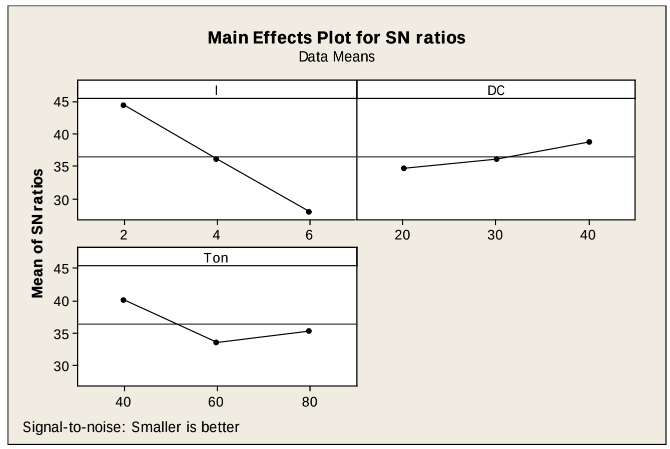

Fig 4 Main effect plot for SN Ratio (EWR)

Fig 4 shows that the EWR decreases with the increase of peak current and increases with increase in duty cycle. But it has a mixed characteristics for pulse on time, it first decrease and the increase with increase of peak current.

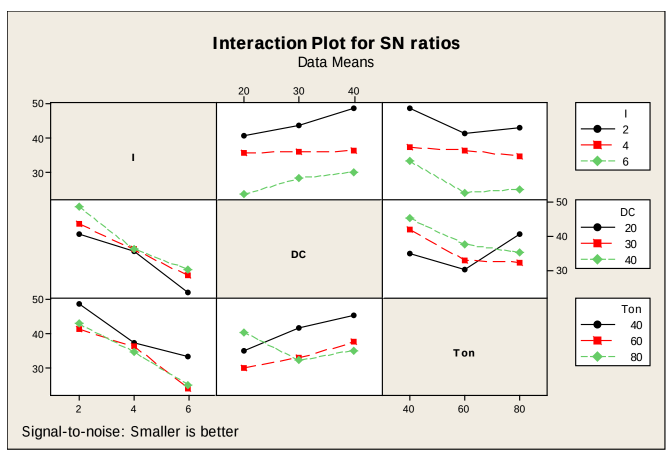

Fig 5. Interection plot for SN Ratio

It is seen from the Figure 5.11 that there is very weak interaction between peak current with the duty cycle in affecting the electrode wear rate since the responses at different levels of process parameters for a given level of parameter value are almost parallel. However, the good interaction of peak current and duty cycle as well as of duty cycle and pulse on time is seen.

TABLE 7. RESPONSE TABLE FOR EWR (S/N DATA)

Level	I	DC	Ton
1	44.43	34.61	40.19
2	36.02	36.09	33.71
3	27.88	38.68	35.48
Delta	16.55	4.07	6.48
Rank	1	3	2

Table 7 includes ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor.

IX. CONCLUSION

The EDM performance of copper tools was examined with AISI D3 tool Steel. In this work, an attempt was made to determine the important machining parameters for performance measures like MRR, EWR. In the EDM process factors like discharge current, pulse duration, and dielectric flow rate and their interactions have been found to play a significant role in operation for maximizations of MRR and EWR. Taguchi's experimental design method is used to obtain optimum parameter combination for maximization of MRR.

- The material removal rate (MRR) mainly affected by peak current (Ip). Duty cycle (DC) has least effect on it.
- The electrode wear rate (EWR) is mainly influenced by peak current (Ip). The effect of gap voltage (Vg) is less on EWR and has least effect on it.

REFERENCES

[1] Y. H. Guu, "AFM surface imaging of AISI D2 tool steel machined by the EDM process", Applied Surface Science 242 (2005) 245–250

[2] Hirotaka KOKUBO, Hideki TAKEZAWA, Ken'ichiro HORIO, Naotake MOHRI, Tsugio YAMAZAKI, "A Study on the Material Removal Mechanism in EDM"

[3] R. A. Mahdavinejad, "Optimization of electro discharge machining parameters", Journal of Achievements in Materials and Manufacturing Engineering volume 27 issue 2 April 2008

[4] S. Prabhu and B.K.Vinayagam, "Analysis of surface characteristics of AISI D2 tool steel material using Electric Discharge Machining process with Single wall carbon nano tube", IACSIT International Journal of Engineering and Technology Vol. 2, No.1, February, 2010 ISSN: 1793-8236

[5] Katsushi Furutani, "Electrical Conditions of Electrical Discharge Machining with Powder Suspended in Working Oil for Titanium Carbide Accretion Process", ISBN No: 981-04-8484-4, 532

[6] S.S.Mahapatra and Amar Patnaik, "Optimization of WEDM process parameters", Indian journal of engineering and material Science Vol 13, December 2006 pp. 494-502

[7] S. Prabhu and B.K. Vinayaga, "Effect of Copper Electrode Material on EDM of AISI D2 Tool Steel with Multiwall Carbon NanotubeUsing Regression Analysis", International Journal of Engineering Studies ISSN 0975- 6469 Volume 1, Number 2 (2009), pp. 93–104