

Optimization of EDM Process Parameters Using Taguchi Method with Graphite Electrode

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Abstract— in this paper experimentation is performed on AISI D3 tool steel using graphite electrode of 10 mm diameter. The process parameters are taken on the basis of Taguchi method. The objective of the paper is to optimize the process parameters of machining in high, medium and low wear factors through duty cycle.

Keywords — EDM process, Taguchi Method.

I. INTRODUCTION

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. Mahdavejad optimized the process parameter Machining of AISI D3 tool 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 Graphite Electrode Material on EDM of AISI D2 Tool Steel using EDM with graphite 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.

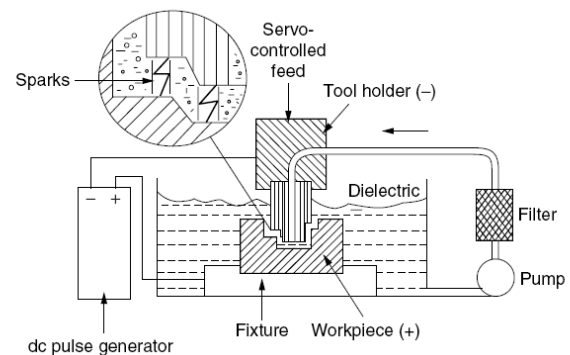


Fig 1: Working principle of EDM

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 graphite is selected as a tool material with the properties listed in Table 2.

TABLE 2
MECHANICAL AND THERMAL PROPERTIES OF GRAPHITE TOOL

Density	1.75 g/cm ³
Melting Point	455 °C
Electrical Resistivity	0.12 micro ohm /cm
Electrical conductivity	0.11 % with Silver
Thermal Conductivity	160W/mK
Specific Heat	0.17-0.2 cal/g°C
Coefficient of thermal Expansion	7.8* 10 ⁻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_a) is the duration of time (in μ s) the current is allowed to flow per cycle. Pulse-off time (t_o) be the duration of time (in μ s) between two consecutive sparks. On the other hand, duty cycle (D) is the ratio of the pulse-on time to the total pulse

VI. EXPERIMENTAL PROCEDURE

During the experiment we have taken total 27 readings on the graphite 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.

time expressed in percentage. Hence it can be expressed mathematically as

$$\text{Duty cycle} = (\text{On time} * 100) / (\text{On time} + \text{off time})$$

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 μ s 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 graphite electrodes are given in the Table 4.

TABLE 4
INITIALS WEIGHTS OF WORK PIECES AND ELECTRODES

No.	Work piece(gm)	Graphite (gm)
1	187.701	7.140
2	188.317	6.940
3	177.565	7.028
4	182.091	6.832
5	177.933	7.246
6	188.900	7.069

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

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
OBSERVATIONS

Peak Current	ON Time	OFF Time	Machining Time	Weight Lost(W)	Weight Lost (E)	MRR(gm/min)	EWR(gm/min)
2	20	30	24.34	0.059	0.004	0.00201315	0.000164339
2	20	13	16.27	0.061	0.005	0.0026429	0.000307314
2	20	5	16.56	0.068	0.004	0.00320048	0.000241546
2	30	45	57.11	0.067	0.002	0.00119068	3.50201E-05
2	30	20	35.5	0.033	0.004	0.00208451	0.000112676
2	30	8	23.26	0.058	0.002	0.00399828	8.59845E-05
2	40	60	35.35	0.058	0.004	0.00031117	0.000113154
2	40	27	25.16	0.054	0.002	0.00158983	7.94913E-05
2	40	10	13.02	0.083	0.003	0.00499232	0.000230415
4	20	30	6.18	0.075	0.003	0.00873786	0.000485437
4	20	13	6.1	0.055	0.003	0.00737705	0.000491803
4	20	5	5.18	0.073	0.002	0.01119691	0.0003861
4	30	45	9.54	0.062	0.001	0.00440252	0.000104822
4	30	20	7.12	0.064	0.002	0.00744382	0.000280899
4	30	8	4.37	0.054	0.002	0.01533181	0.000457666
4	40	60	33.01	0.08	0.002	0.00172675	6.05877E-05
4	40	27	13.49	0.081	0.002	0.00429948	0.000148258
4	40	10	8.13	0.071	0.001	0.00615006	0.000123001
6	20	30	3.28	0.112	0.003	0.02835366	0.000914634
6	20	13	3.2	0.068	0.003	0.0221875	0.0009375
6	20	5	2.38	0.079	0.003	0.02521008	0.001260504
6	30	45	5.05	0.074	0.004	0.01524752	0.000792079
6	30	20	1.43	0.072	0.001	0.05314685	0.000699301
6	30	8	2.15	0.082	0.002	0.0372093	0.000930233
6	40	60	7.21	0.067	0.002	0.00970874	0.000277393
6	40	27	2.55	0.091	0.003	0.03490196	0.001176471
6	40	10	0.45	0.102	0.004	0.22444444	0.008888889

VII. RESULT ANALYSIS

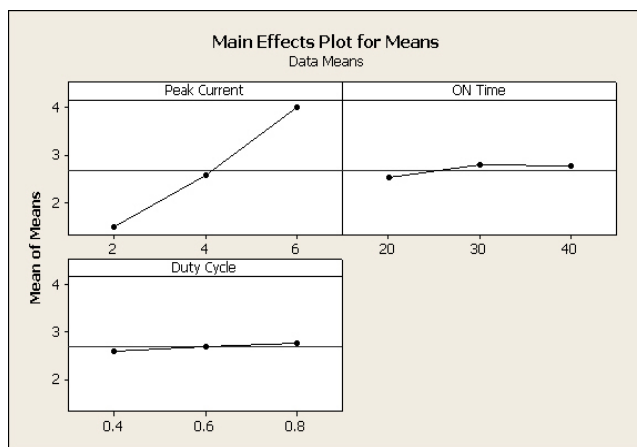


Fig. 2 Main Effects Plot for Means

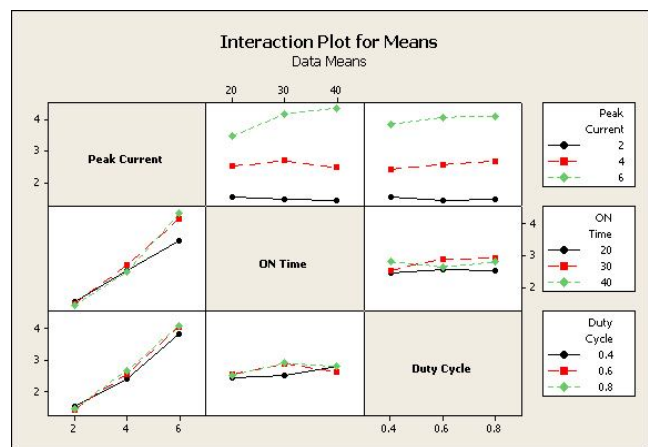


Fig. 3 Interaction Plot for Means

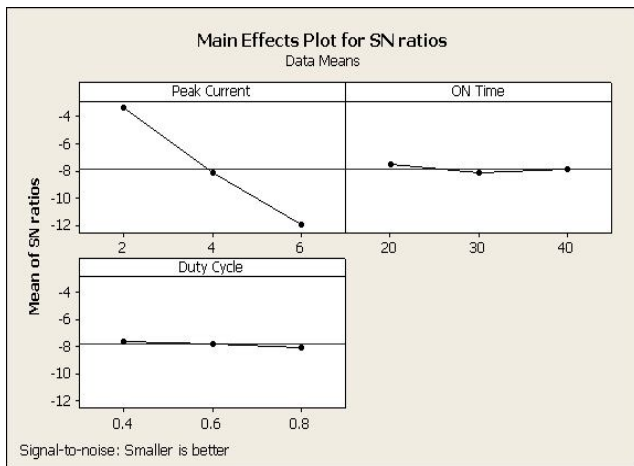


Fig. 4 Main Effects Plot for SN ratios

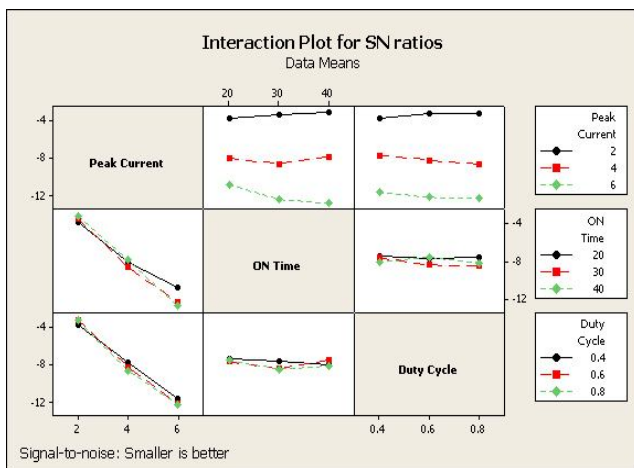


Fig. 5 Interaction Plot for SN ratio

VIII. CONCLUSION

The EDM performance of graphite 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, TWR. 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. 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 (I_p). Duty cycle (t) has least effect on it.
- ✓ The electrode wear rate (EWR) is mainly influenced by peak current (I_p). The effect of gap voltage (V_g) is less on EWR and has least effect on it.

ACKNOWLEDGMENT

The authors are thankful to faculty members, and laboratory assistance staff for giving full support during the performance of the experiment. And extremely thankful to the principle for his motivation during research work.

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