Optimization of Process Parameters in Electrical Discharge Machining of OHNS by using RSM's Response Optimizer

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Abstract— Electric discharge machining (EDM) is a non-traditional machining process; it is a well-established machining option in many manufacturing industries throughout the world. There are no physical cutting forces between the tool and work piece while removing the material, it only uses thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage in the manufacturing industries. (OHNS) Oil Hardening Non Shrinking Die Steel is an ideal type of oil hardened steel economical for manufacturing Industries. It is generally used for Blanking and Stamping dies, Gauging tools, Wood working tools etc. This paper reports the results of an experimental investigation carried out to study the effects of machining parameters such as current, voltage and pulse on time on material removal rate and tool wear rate in electrical discharge machining of OHNS by using copper electrode. The process has been successfully carried by Response surface methodology (RSM) and model adequacy is carried out by using Minitab software. While RSM's D-Optimal Method is used to solve the multi-response optimization. To validate the optimum levels of the parameter, confirmation run was performed by setting the parameters at optimum levels. It is observed that voltage is most significant parameter for material removal rate and tool wear rate followed by pulse on time and current.

Key words: Electric Discharge Machine, Material Removal Rate, Response Surface Methodology, Tool Wear Rate

I. INTRODUCTION

The recent developments in the field of EDM have progressed due growing application of EDM process, it is used to do the machining of new materials that are hard and difficult to machine, such as tool steels, super alloys, heat resistant steels etc. used in aerospace, aeronautics and nuclear industries. These materials also find applications in other industries because of their high strength to weight ratio, hardness and heat resisting qualities [1-2].

At the present Electrical discharge machining is widespread technique used in industry for high precision machining for all types of conductive materials such as metals, metallic alloys, ceramic materials, super alloys etc. of whatever the intensity of hardness [1]. EDM is used in the industries like aeronautics, automobiles, nuclear reactors, missiles, turbines etc. materials like high strength temperature resistant alloys which have higher strength, corrosion resistance, toughness and other diverse properties [2]. The major advantage of EDM is that the machining process enables us to obtain components with desired shape and closer dimensional tolerance in a shorter time, compared to that in case of traditional machining process [3]. As both electrode and work piece being electrically conductive possess sufficient amount of free electrons, this free electrons are plugged towards the work piece these emitted electrons stick on dielectric molecules and ionize them. Now in spark gap there are free electrons and ions which undergo collusion due to avalanche motion between them leads to development of new state of matter called "plasma". Thus plasma channel is set up between tool and work piece and the temperature goes high around 80000C-120000C. Thus surface layer of work piece is rapidly melted by a spark at each charge point. In this way, small volume of work piece material is removed by mechanism of melting and vaporization because of sparking [4]. EDM parameters namely voltage range, impulse frequency, dielectric fluid pressure, type of flushing and electrode material are the most affecting parameters. It was found that these parameters have significant influence on machining characteristics such as machining rate, tool erosion rate, volumetric wear ratio and surface finish. Since long EDM is widely used in industry to machine „difficult to machine materials" like HCHC steel (tool and die material.

EDM is preferred material removal process due to advantages like reduced machining stresses, lesser work hardening effects and lesser metallurgical damage. (OHNS) Oil Hardening Non Shrinking Die Steel is an ideal type of oil hardened steel economical for manufacturing Industries. It is generally used for Blanking and Stamping dies, Gauging tools, Wood working tools etc. studies show that selection of process variables and fixing the appropriate range of parameters to machine every product, decide the quality of the product and in turn design requirements Shankar sing et.al (2004) [2].considering the research done by others on different work materials and taking into account of the machining characteristics of OHNS Die steel, EDM experiments were carried out with copper electrode and analyzed for their adaptability to material. In this work material removal rate and tool wear rate are considered for the performanance of EDM. Experiments were carried out with copper electrodes of diameter 10 mm, and analyzed for their adaptability to this material. Machining parameters optimization has been carried out through response surface methodology, utilizing the relevant experimental data and optimum values of input parameters were found using RSM's D-optimal method.

II. EXPERIMENTAL SET UP

A. *Machine Tool & Dielectric Medium*

All the experiments where performed on Electrical Discharge machine. The machine has the provisions of programming in the Z-vertical axis control and manually operating X and Y axes. EDM oil is used as dielectric medium. oil having dielectric strength 45 kW was used as a dielectric medium at a flushing pressure of 0.25 kg/cm3. A jet flushing system is used in order to assure the adequate flushing of debris from the gap zone was employed.

The oil formulated with a highly refined, narrow cut paraffinic base stock with excellent oxidation stability which helps reduce the formation of oxidation products that will alter the dielectric strength of the fluid. The oil is colorless and virtually odorless, exhibits a relatively high flash point that helps to reduce the possibility of fire. The low viscosity of the fluid provides good circulation through the spark gap and more rapid removal and settling of metal fines. The dielectric fluid should possess two conflicting properties that is the spark conductor that must ionize under the applied voltage at the same time it should not get break down in the spark gap. It should acts as flushing medium that carries away the melted material.

A depth of cut of 5 mm was set for the machining of all the work piece samples. Finally the required power switches were switched 'ON' for operating the desired input values. After the machining operation, the electrode and work piece were taken out and weighed again. The operational time was measured by using stop watch for each hole. The same experiments were performed for all the input parameters settings.

B. *Work Piece Material*

The work material chosen for the experimental purpose was OHNS. Total 20 holes are machined by using copper electrode of diameter 10 mm over 4 plates of size (110×20×4) mm. (OHNS) Oil Hardening Non Shrinking Die Steel is an ideal type of oil hardened steel economical for manufacturing Industries. It is generally used for Blanking and Stamping dies, Gauging tools, Wood working tools etc. The chemical composition & Physical properties of OHNS are listed in table.

Element	Composition (% of Wt.)
Carbon	0.82
Silicon	0.18
Manganese	0.52
Chromium	0.49
Tungsten	-
Vanadium	0.19
Molybdenum	0.13
Nickel	0.05
Iron	Balance

Table 1: Chemical composition of OHNS

C. *Electrode Material*

With the Advancement in EDM Copper becomes the metallic Electrode material of preferences. Again due to its tool making culture that is adverse to untidiness of working with Graphite, Copper is generally preferred as electrode of choice. For experimental purpose copper electrode of diameter 10 mm is employed. The physical properties of copper electrode are listed in table.

Specific gravity (g/cm^3)	8.94
Melting range (^{0} C)	1065-1083
Thermal Conductivity (W/m-k)	388
Specific heat (J/kg-k)	385
Electrical resistivity (ohm-cm)	1.7×10^{-6}
Thermal expansion co-efficient (1/ 0C)	16.7×10^{-6}

Table 2: Physical properties of copper electrode

D. *Machining Parameters & Their Levels*

Parameter	-1	0	1
Current (X_1) A	10	20	30
Voltage (X_2) V	30	40	50
Pulse-on time (X_3) µS	400	500	600

Table 3: Levels & Values of Operating Parameter

III. Response Variables Selected

Material removal rate and tool wear rate are considered as a response parameters they are defined as follows:
The material removal rate is expressed as the ratio of the of weight of the work piece before and after the machining to machining time as shown in eq.(1)

$$MRR = W_{tb} - W_{ta}/T \quad (1)$$

Where
W_{tb}-Weight of work piece before the machining (gm)
W_{ta}- Weight of work piece after the machining (gm)
T -Time consumed for the machining (min)
The tool wear rate is expressed as the ratio of the of weight of the tool before and after the machining to machining time as shown in eq. (2)

$$TWR= \quad Wtb -Wta/T \quad (2)$$

Where,
W_{tb} - Weight of tool before the machining (gm)
W_{ta}- Weight of tool after the machining (gm)
T - Time consumed for the machining (min)

IV. Method of Experimentation

Response surface methodology (RSM) is a collection of mathematical and statistical techniques useful for analyzing problems in which several independent variables influence a dependent variable or response, and the goal is to optimize this response. In many experimental conditions, it is possible to represent independent factors in quantitative form as given in equation 2.1. Then these factors can be thought of as having a functional relationship with response as follows

$$Y= \phi\ (x1, x2,x3.................xk) + er \quad (3)$$

This represents the relation between response Y and x_1, x_2… x_k of k quantitative factors. The function ϕ is called response surface or response function. The residual er measures the experimental errors. For a given set of independent variables, a characteristic surface is responded. When the mathematical form of Φ is not known, it can be approximated satisfactorily within the experimental region by a polynomial. Higher the degree of polynomial better is the correlation but at the same time costs of experimentation become higher.

A. *Response Surface Design*

The present article gives the application of the response surface methodology. The scheme of Carrying out experiments was selected and the experiments were conducted to investigate the effect of process parameters on the MRR. The experimental results will be discussed subsequently in the following sections. The selected process variables were varied up to three levels and face-centered central composite design was adopted to design the experiments as shown in figure 1. Response Surface Methodology was used to develop second order regression equation relating response characteristics and process variables.

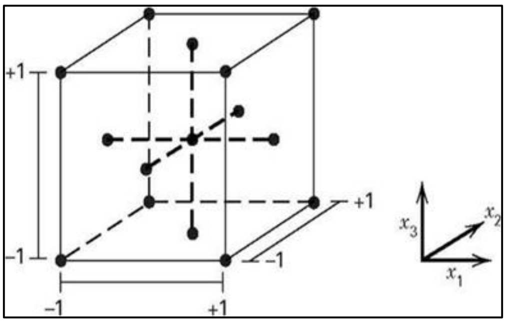


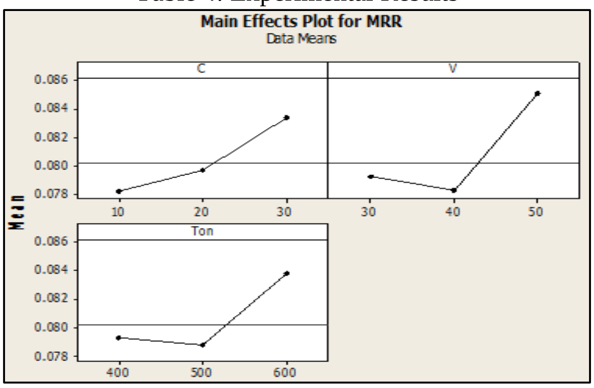
Fig. 1 Face centered central composite design for k=3

V. EXPERIMENTAL RESULTS & OPTIMIZATION

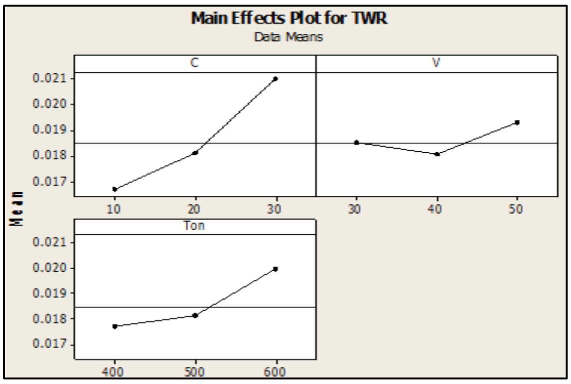
RSM approach was employed for designing as well as for finding out optimal solutions. The following results are obtained as shown in table

Expt. No.	Process Parameters			Response Parameters	
	X_1	X_2	X_3	MRR (gram/min)	TWR (gram/min)
1	10	40	500	0.0747	0.0167
2	20	30	500	0.0795	0.0183
3	30	40	500	0.0775	0.0202
4	20	40	400	0.0792	0.0177
5	20	40	500	0.0786	0.0184
6	20	50	500	0.0867	0.0192
7	20	40	500	0.0784	0.0172
8	20	40	600	0.0812	0.0191
9	10	50	400	0.0782	0.0158
10	10	30	600	0.0783	0.0177
11	20	40	500	0.0771	0.0178
12	30	30	400	0.0782	0.0193
13	20	40	500	0.0789	0.0174
14	30	50	600	0.0879	0.0229
15	20	40	500	0.0781	0.0178
16	30	50	400	0.0871	0.0206
17	20	40	500	0.0787	0.0182
18	10	50	600	0.0855	0.018
19	30	30	600	0.0862	0.0221
20	10	30	400	0.074	0.0153

Table 4: Experimental Results



(a) Main effects plots for MRR



(b) Main Effects Plots for TWR

Fig. 2: Main Effects Plots

The mail effect plot between current, voltage and pulse on time for MRR and TWR are shown in figure 2 (a) and (b) respectively. Figure shows that with the increase of current and pulse on time the MRR and TWR increases gradually. Initially TWR is decreases with increase in voltage because deposition of carbon layer on tool and work piece and then it increases. The increase in MRR with the increase in discharge current is because the spark discharge energy is increases to facilitate the action of melting and vaporization, and advancing the large impulsive force in the spark gap, thereby increasing the MRR. Therefore, the larger current results in deeper craters, which increase the material removal and tool wear rate.

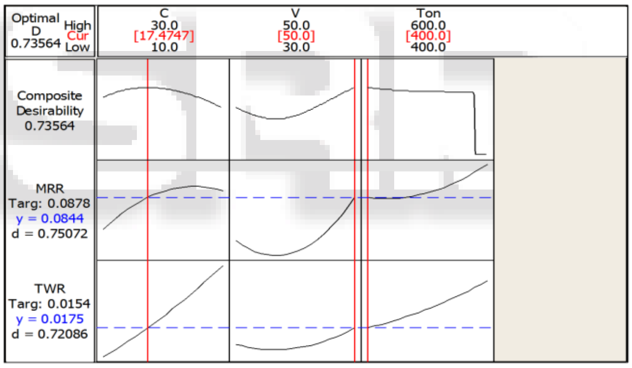


Fig. 3: Optimization Plot

The figure 3 shows that the optimizations plot for material removal rate and tool wear rate. The ultimate objective of our work was to maximize the MRR and minimize the TWR. The desirability approach was used for finding out the optimum values of material removal rate and tool wear rate. From the figure 3 it clear that the highest value of MRR is 0.0844 gm/min and the lowest value of TWR is 0.0175 gm/min which is obtained at optimum values of input parameters.

VI. CONCLUSION

The hole-drilling experiments were successfully performed on OHNS using copper electrode and the material removal rate is evaluated.

- MRR and TWR increases directly with increase in current and the maximum material removal rate is obtained at 50 V.
- As voltage increases initially the MRR and TWR is decreases and then increases

- Voltage is most affecting parameter for MRR and While current most affecting parameter for TWR.
- The optimal values of process parameters which have composite desirability 0.74 are current 17.47 (A), voltage 50(V) and pulse on time 400 (µs).

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