Wear Rate of Copper Electrode in Chromium Abrasive Suspended Kerosene Oil Dielectric during EDM of OHNS die Steel

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***Abstract*—This experimental investigation is dedicated to study rate of tool elected wear in sinking electro discharge machining (EDM) process. Pure kerosene oil and chromium abrasives added kerosene oil dielectrics are used and experiments are performed on OHNS steel using OSCARMAX S645 CNC sinking EDM machine. Taguchi method has been used to design and examine the performance of process. Polarity, current, pulse on time, pulse off time, gap voltage and amount of chromium abrasives mixed in kerosene oil as dielectric fluid were selected as inputs to the process. Taguchi recommended orthogonal array is used to plan the experiments. The outcome of this study provides highly valuable data to minimize tool electrode wear rate.**

Keywords—Abrasive mixed EDM; OHNS steel; Electrode wear rate

I. INTRODUCTION

Joseph Priestly, in 1770 was the first [1] who discovered that the electrical discharges can erode metal. A long time is elapsed to convert this discovery into a real and controlled process called electro discharge machining process. Originally inefficient, poor performance with low output conventional EDM process used only in the tool rooms and not in the production lines of industries. Coupling of computer-numeric-control technology with electro-discharge-machining technology in 1980 [3] and since then this electro-thermal process became the leading research potential area to work among all non conventional processes. Capability to cut precisely for intricate shapes [4] on softest to hardest conductive materials without much thermal damage and mechanical failure of tool used are among the notable advantages of the process. Since 1940s, researchers tried various innovative ideas to remove above said deficiencies and make EDM process a more stable, capable and efficient process [2]. These ideas include addition of foreign particles [5-7] into the dielectric of process, use of composite electrode tools, use of vibrating electrodes, etc. Additive EDM known for its high machining rate coupled with good surface finish, a revolutionary technique which established EDM as competitive machining technique [8-9]. Many researchers listed in [6] [10] [11] and [12] tried various powders of conductive materials and studied their influence on output response like base material cutting rates, efficiency of the process, wearing rates of tool used, quality of surface produced, and properties of fluid itself etc.

This work is focused to study the rate of wear of tool electrode in sinking EDM process. Here, use of the design of experiments methodology is made to study wear rate (of solid copper electrode) in EDM sinking experiments on OHNS steel. Percentage content of chromium abrasives is varied in kerosene oil (used as dielectric) in experiments performed both at positive and negative polarity.

II. MATERIAL USED AND TAGUCHI'S PLANNING STRATEGY

A 40 mm thick rectangular cross-section plate of OHNS die steel and 9 mm diameter solid copper rod are used as workpiece material and tool electrode respectively. Chemical composition of OHNS die steel consists of .82% C, .18% Si, .52% Mn, .49% Cr, .19% V, .13% Mo, .05% Ni and balanced Fe. Architecture of experimental runs is planned as per Taguchi methodology. An L_{18} mixed level orthogonal array with eighteen rows is selected to vary the range of process inputs. Table I gives the process inputs, levels and variation range values.

TABLE I. PROCESS INPUTS, LEVELS AND THEIR RANGE OF VARIATION

Process Input	First level of Input	Second level of Input	Third level of Input
Polarity of Cu tool electrode	Positive	Negative	--
Current (amp)	4.0	8.0	12.0
Pulse on time (µs)	90.0	150.0	200.0
Pulse off time (µs)	30.0	45.0	60.0
Gap voltage (volt)	30.0	40.0	50.0
Concentration of chromium abrasives in kerosene (g/l)	0.0	5.0	10.0

Keeping objectives of this experimental work into mind, appropriate signal to noise (S/N) equation (for lower the better response criterion) was selected as shown in Eq. (1).

$$\left({}^{S}/_{N}\right)_{EWR} = -10 \log \left[\frac{1}{K}\sum_{s=1}^{K}\left(\frac{1}{m_s^2}\right)\right] \qquad (1)$$

In Eq. (1); m_s = observed value of EWR
K = no. of repetitions

OSCARMAX S645 CNC sinking EDM machine (Fig. 1) with integrated servo mechanism is used to conduct experiments. Wear rate of tool electrode is calculated using Eq. (2)

$$EWR = \frac{\Delta E_w}{T_m} \qquad (2)$$

In Eq. (2), the ΔE_w and T_m are the loss of material from tool electrode in a cut and machining time for the cut respectively.

Fig. I. OSCARMAX S645 CNC SINKING EDM MACHINE

III. RESULT OBTAINED AND DISCUSSIONS

Taking the range of variation of inputs as per orthogonal array plan and to avoid impact of unaccounted parameters, all the eighteen experimental runs are performed randomly and the output is recorded for EWR. Calculated values of EWR, process input matrix adopted with signal to noise ratio values is shown in Table II.

TABLE II. TAGUCHI ORTHOGONAL ARRAY L_{18} WITH EWR & S/N RATIO VALUES

Experiment No.	Polarity	Current	Pulse on time	Pulse off Time	Voltage	Concentrat. of Cr. abrasives	EWR (g/min)	S/N ratio (dB)
1	1	1	1	1	1	1	0.00054	65.29636
2	1	1	2	2	2	2	0.00050	66.0206
3	1	1	3	3	3	3	0.00030	70.41753
4	1	2	1	1	2	2	0.00333	49.54243
5	1	2	2	2	3	3	0.00272	51.31696
6	1	2	3	3	1	1	0.00240	52.40272
7	1	3	1	2	1	3	0.00730	42.73441
8	1	3	2	3	2	1	0.00508	45.88932
9	1	3	3	1	3	2	0.00508	45.88932
10	2	1	1	3	3	2	0.00058	64.69372
11	2	1	2	1	1	3	0.00055	65.17411
12	2	1	3	2	2	1	0.00055	65.17411
13	2	2	1	2	3	1	0.00173	55.2302
14	2	2	2	3	1	2	0.00198	54.06828
15	2	2	3	1	2	3	0.00162	55.81776
16	2	3	1	3	2	3	0.00115	58.80464
17	2	3	2	1	3	1	0.00143	56.87503
18	2	3	3	2	1	2	0.00228	52.83515

TABLE III. ANOVA & F-TEST VALUES (S/N DATA)

Source	DOF	Seq SS	Adj SS	Adj MS	Calculated 'F' Value	Critical 'F' value	P Value	Contribution (%).
Polarity	1	85.21	85.209	85.209	3.56	05.99	0.108	7.66
Current	2	842.82	842.816	421.408	17.59	05.14	0.003	75.74
Pulse on time	2	3.24	3.240	1.620	0.07	05.14	0.935	0.29
Pulse off time	2	14.17	14.167	7.083	0.30	05.14	0.754	1.27
Voltage	2	12.68	12.684	6.342	0.26	05.14	0.776	1.14
Concen. of Cr. abrasives	2	11.03	11.026	5.513	0.23	05.14	0.801	0.99
Residual error	6	143.71	143.711	23.952				12.91
Total	17	1112.85						

ANOVA of observed data values is performed to obtain the %age contribution and significance of each of six inputs towards improvement of EWR. Statistically calculated values of ANOVA and F-Test are given in table III. Results of EWR are taken as 'smaller the better' criterion. In table III, F-critical value is taken from statisticians' tables. Statistically calculated f-value of peak current is 17.59, which is more than f-values of other inputs. This shows that %age contribution of peak current is highest (75.74%). Also 0.003 p-value of peak current shows significant contribution of this input at 95% confidence level. P-value of other inputs is more than 0.05 at same confidence level which shows their insignificant contribution towards EWR. Graphically in main effects plot the general effects (S/N data) of all inputs is given in fig. 2. Following Taguchi guidelines, highest level of input gives the desired response value. Experimentation at negative tool polarity level favors the desired response i.e. lower the EWR. Low value of peak current is desirable for lowering the EWR because at low currents, the sparks are having low discharge energy which is not capable to erode much volume of OHNS plate material. This discharge energy increases per spark at higher input peak current value and erodes comparatively more material from work surface. So, first level of peak current is favorable for the desirable response value. Slope of curves of EWR variation with all levels of other inputs made clear about their non significant contribution towards process output. Therefore, polarity at second level, peak current at first level, pulse on time at third level, pulse off time at third level, gap voltage at third level and chromium concentration at third level gives the desired response i.e. minimum EWR. Delta static value is calculated by taking minimum and maximum S/N ratio value for each input and associated level (Table IV). This value is useful to decide the relative magnitude of effect of inputs in the process. Generally more the delta value more is the input effect in the process. Overall, largest delta value (15.62) for peak current and smallest delta static (1.04) for pulse on time decides their role as most influential input and least influential inputs respectively as far as the EWR performance is taken.

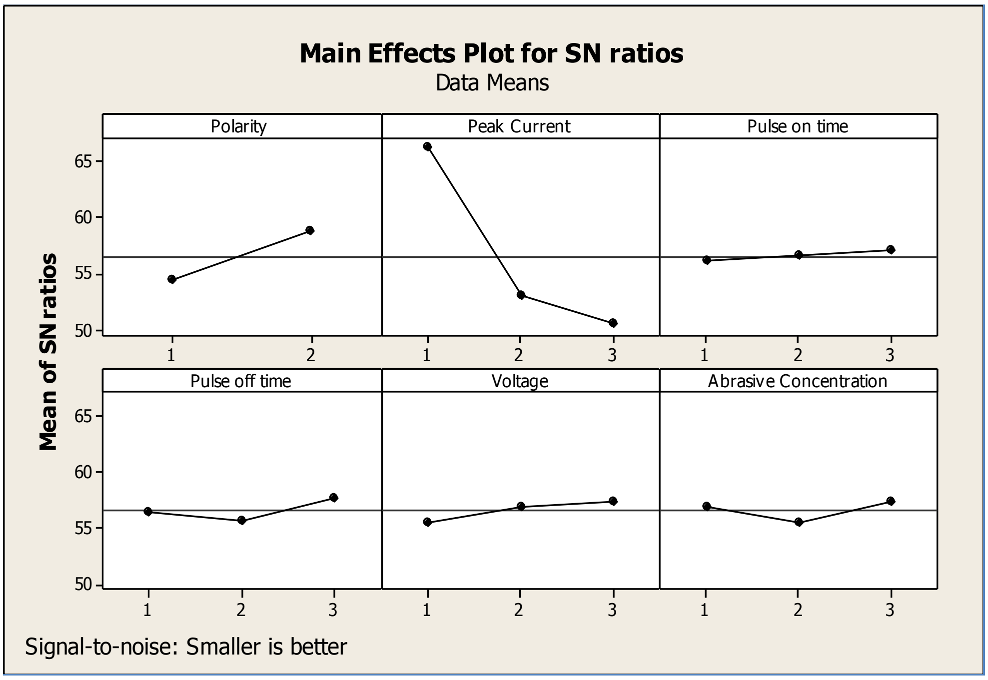

Fig. II. MAIN EFFECT PLOT FOR S/N RATIO (FOR EWR)

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

Level	Polarity	Peak current	Pulse on time	Pulse off Time	Gap voltage	Concentration of abrasives	Mean Value
1	54.39	66.13	56.05	56.43	55.42	56.81	57.54
2	58.74	53.06	56.56	55.55	56.87	55.51	56.05
3		50.50	57.09	57.71	57.40	57.38	46.68
Delta	4.35	15.62	1.04	2.16	1.99	1.87	
Rank	2	1	6	3	4	5	

Further in table 4, the 58.74 value at second level of polarity, 66.13 value at first level of peak current, 57.09 value at third level of pulse on time, 57.71 value for third level of pulse off time, 57.40 value third level of gap voltage and 57.38 value at third level of abrasive concentration are the biggest values for associated inputs. These values tell the optimum input levels for minimum tool EWR.

IV. CONCLUSIONS

Taguchi method is applied to study tool EWR for smaller the better criterion. In accordance with experimental outcomes following conclusions are made:

1) Taguchi method is capable to study EWR performance of abrasive EDM process.
2) Possible input level combination is obtained for minimum EWR performance of present process.
3) EWR increases sharply with very high energy generation because it erodes more material from tool electrode.
4) Peak current is significant input for deciding wearing of copper tool electrode in the process.
5) Experimental proved results will be useful for industrial applications engaged in machining OHNS die steel material.

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