Multi-Response Optimization of Electric Discharge Machining (EDM) process

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Abstract : In the present study, the performance parameters of EDM process are to be evaluated to achieve the feasibility in machining of H13 tool steel which has wide application in the Hot punches and dies for blanking, forging, swaging and bending, Nozzles for aluminum, tin and lead die casting, Hot extrusion dies for aluminum, cores ejector pins, inserts, Hot shear blades. The important process parameters that have been selected are peak current, pulse on time and pulse off time. The outputs responses are material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR). Here the machining is done by EDM using two different electrodes like Copper, and Bronze and investigate which type of electrode gives better result for increasing MRR, decrease SR and lower EWR. The experiments were planned, conducted and analyzed using Response surface methodology and analysis of variance (ANOVA) has been applied to identify the significant process parameters.

Keywords - EDM, Material removal rate, Electrode wear rate, Surface roughness, Response surface method, ANOVA

I. INTRODUCTION

Electrical Discharge Machining, commonly known as EDM is a non-conventional machining method used to remove material by a number of repetitive electrical discharges of small duration and high current density between the work piece and the tool. EDM is an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. In EDM, since there is no direct contact between the work piece and the electrode, hence there are no mechanical forces existing between them. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material. EDM has been substituting traditional machining operations. Now-a-days EDM is a popular machining operation in several manufacturing industries all over the world's countries. Most of the traditional machining process such as drilling, grinding and milling, etc. are failed to machine geometrically complex or difficult shape and size. Those materials are easily machined by EDM non-traditional machining process which leads to broadly utilized as die in addition to mould assembly industries, making aeronautical parts and nuclear instruments at the minimum cost. Electric Discharge Machining has also established its presence touched on the different subject areas such as make use of sporting things, medicinal and clinical instruments as well as motorized research and development regions.

II. LITERATURE REVIE

T Muthuramalingam et al. applied Taguchi-grey relational approach based multi response optimization has been used to maximize material removal rate and to minimize surface roughness in EDM using AISI 202 stainless steel as work piece and brass as tool electrode. Electrical process parameters such as gap voltage, peak current and duty factor have been used as input parameters**.[1].**

S Gopalakannan et al. performed experiment on the newly engineered metal matrix composite (MMC) of aluminium 7075 reinforced with 10 wt% of B_4C particles were prepared by stir casting method by Copper electrode. Experiments were carried out by adopting face centered composite design of response surface methodology. Analysis of variance was applied to investigate the influence of process parameters and their interactions viz., pulse current, gap voltage, pulse on time and pulse off time on material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR).**[2]**

P. Balasubramanian et al. performed experiments on EN8 and D3 steel materials by Cast Copper and Sintered Powder Metallurgy Copper (P/M Copper) electrodes applying Response surface methodology (RSM) to analyze the parameters and analysis of variance (ANOVA) has been applied to identify the significant process parameters. The outputs responses are material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR).**[3].**

Pardeep Narwal et al. conducted experiments by Copper electrode on H13 tool steel work material. They selected process parameters like peak current, Pulse on Time, and Feed rate on Material Removal Rate for the response variables Taguchi technique was used.**[4]**

Sadu Venkatesu et al. worked on optimization of multiple responses of Electric discharge machining (EDM) using Fuzzy method coupled with Taguchi is attempted. The work piece material was AISI 304 Stainless Steel and a cylindrical copper electrode with side impulse flushing was used.**[5]**

The main objective of this paper is to make comparative study between Copper and Bronze electrode using EDM machine. To analyze which electrode is better for increased MRR, low SR and low EWR and optimize the effect of process parameters on output responses using Response Surface methodology.

III. EXPERIMENTAL DETAILS

3.1 Procedure

The equipment used for conducting experiments is SPARKONIX-S (25A) die-sinking EDM machine as shown in fig.1. H13 tool steel has been prepared to the size of 100×40×10 mm and top surfaces were fine finished. The work material was machined by using two different electrodes namely Copper and Bronze electrode. Both of the electrode have same diameter of 19 mm. During experiments, care has been taken so that the face of the tool is parallel to the work piece. Weight of the work segments and tools has measured, before machining and after machining, on Electronic weighing machine. The average surface roughness was measured using surface roughness tester.

fig. 1- SPARKONIX-S 25 Die-sinking EDM machine

3.2 Equation of MRR (mm^3/min)

$$MRR = \frac{Wi - Wf}{\rho t}$$

where, W_i = Initial weight of work piece, W_f = Final weight of work piece, ρ = Density H13 tool steel is 7750kg/m^3, t = Machining time

3.3 Equation of EWR (gm/min)

$$EWR = \frac{Ti - Tf}{t}$$

where, T_i = initial weight of electrode in gm, T_f =final weight of electrode in gm, t = time consumed for machining

IV DESIGN OF EXPERIMENT

In the present study the experiments were designed based on Central composite design of Response Surface Method. The factorial portion of Central composite design is a full factorial design with all combination of the factors at three levels (-1, 0, +1). The `Face- centered CCD involves 40 experimental observations at three independent input variables. EDM process parameters and their levels are as shown in Table 1 as per DOE-11

Table 1- Process parameters and their levels

FACTOR	LEVELS		
	(-1)	(0)	(1)
CURRENT(amp)	12	18	24
PULSE ON TIME (μs)	6	7	8
PULSE OFF TIME (μs)	5	6	7

V ANALYSIS AND DISCUSSION

5.1 Final Equation in Terms of Actual Factors for Copper Electrode

MRR = 0.0073 + 0.0202*A – 0.0096*B + 0*C – 0.0062*AB + 0.0013*AC + 0.0016*BC + 0.0083*A^2 + 0.0108*B^2

SR = 54.78 + 20.51*A + 3.56*B – 2.78*C – 2.41*B^2

EWR = 12.03 + 1.93*A – 0.3570*B + 0.560*C + 0.7225*AB – 0.4525*AC + 0.4275*BC + 0.1168*A^2 + 0.9368*B^2 – 1.38*C^2

5.2 Final Equation in Terms of Actual Factors for Bronze Electrode

MRR = 0.0072 + 0.0202*A – 0.0096*B + 0.00*C – 0.0062*AB + 0.0013*AC + 0.0016BC + 0.0081*A^2 + 0.0105*B^2 + 0.0007*C^2

SR = 54.78 + 20.51*A + 3.56*B – 2.78*C – 2.41*B^2

EWR = 12.03 + 1.93*A – 0.3570*B + 0.5600*C + 0.7225*AB – 0.4525*AC + 0.4275*BC + 0.1168A^2 + 0.9368*B^2 – 1.38*C^2

Where, A= Current, B= Pulse on time and C= Pulse off time

Table 2- Design matrix table on H13- Copper electrode

Sr No.	Current(I) (ampere)	Pulse On Time (µs)	Pulse Off Time (µs)	Weight of w/p before machining (gm)	Weight of w/p after machining (gm)	Time (minute)	MRR mm^3/min	EWR gm/min	SR µm
1	24	6	7	568.940	563.830	10.18	64.769	0.06394	13.91
2	12	8	7	245.520	240.930	20.93	28.297	0.000764	10.33
3	24	8	7	554.04	549.08	8.28	77.294	0.03695	13.85
4	24	7	6	563.830	558.920	8.43	75.154	0.02645	13.39
5	18	7	6	231.680	226.730	11.42	55.929	0.006654	12.3
6	12	7	6	255.660	250.910	17.73	34.568	0.005471	10.66
7	18	7	6	476.430	471.610	11.47	54.223	0.007062	12.14
8	24	6	5	573.710	568.940	8.52	72.239	0.06502	13.45
9	18	7	6	471.610	466.60	11.32	57.107	0.004682	12.05
10	18	7	6	466.60	461.68	11.35	55.933	0.006872	11.9
11	12	8	5	250.910	245.520	17.58	39.561	0.000626	6.35
12	18	7	7	545.730	540.880	12.63	49.549	0.008076	11.22
13	18	6	6	240.930	236.420	12.23	47.583	0.029	12.24
14	18	7	6	461.68	456.89	11.03	56.034	0.007706	12.1
15	12	6	5	265.250	260.82	18.57	30.78	0.009316	11.01
16	18	8	6	550.620	545.730	11.08	56.946	0.007762	13.45
17	12	6	7	260.82	255.660	23.18	28.72	0.004443	10.95
18	18	7	6	540.880	536.170	11.45	53.078	0.008034	12.15
19	24	8	5	558.920	554.04	8.12	77.546	0.02992	14.01
20	18	7	5	236.420	231.630	10.87	56.266	0.00902	9.84

Table 3- Design matrix table on H13- Bronze electrode

Sr No.	Current(I) (ampere)	Pulse On Time (µs)	Pulse Off Time (µs)	Weight of w/p before machining (gm)	Weight of w/p after machining (gm)	Time (minute)	MRR mm^3/min	EWR gm/min	SR µm
1	24	6	7	126.747	124.341	11.98	25.914	0.203	12.19
2	12	8	7	196.087	192.675	23.27	18.919	0.0657	5.3
3	24	8	7	118.499	115.358	8.83	45.899	0.2809	13.2
4	24	7	6	124.341	121.490	8.95	41.102	0.2375	13.81
5	18	7	6	187.623	1844.935	12.40	27.97	0.1641	8.45
6	12	7	6	202.380	199.297	21.05	18.898	0.09396	10.3
7	18	7	6	171.332	168.539	12.25	29.42	0.1737	8.36
8	24	6	5	449.004	446.372	9.83	34.548	0.238	10.3
9	18	7	6	168.539	165.786	12.32	28.833	0.1687	8.39
10	18	7	6	165.786	162.984	12.33	29.322	0.1694	8.35
11	12	8	5	199.297	196.087	19.40	21.35	0.0685	5.6
12	18	7	7	454.602	451.819	14.06	25.54	0.1472	9.32
13	18	6	6	192.675	190.161	12.43	26.097	0.1959	7.9
14	18	7	6	162.984	160.184	12.28	29.42	0.1728	8.28
15	12	6	5	207.460	204.920	23.05	14.218	0.1015	8.35
16	18	8	6	451.819	449.004	12.92	28.113	0.1612	8.55
17	12	6	7	204.920	202.380	31.53	10.395	0.0779	10.26
18	18	7	6	457.513	454.602	12.23	30.712	0.1688	8.25
19	24	8	5	121.490	118.499	8.53	45.244	0.2942	12.9
20	18	7	5	190.161	187.623	10.93	29.962	0.1781	8.21

5.3 Effect of Process Parameters on Responses

5.3.1 Pulse Current

Pulse current is most significant parameter of EDM process. As the pulse current increases MRR also increases for both Copper and Bronze electrode and EWR is also increases as shown in Figure 1 and Figure 4 respectively. As current increases surface roughness also increases as shown in Figure 2. As increasing current EWR increases for both electrodes but, for Bronze electrode EWR is very higher as compared to Copper electrode.

5.3.2 Pulse on time

Pulse on time is the second most influencing process parameter on machining process. As pulse on time increases MRR and SR increases as shown in Figure 1 and Figure 2. EWR increases as pulse on time increases also.

5.3.3 Pulse off time

Pulse off time has lower effect as compared to current and pulse on time on machining process. As pulse off time increases, MRR decreases as shown in Figure 3. As pulse off time increases, lower surface roughness is achieved. This is due to the fact that as higher pulse off time will provide some more time for flushing out the carbon and removed material.

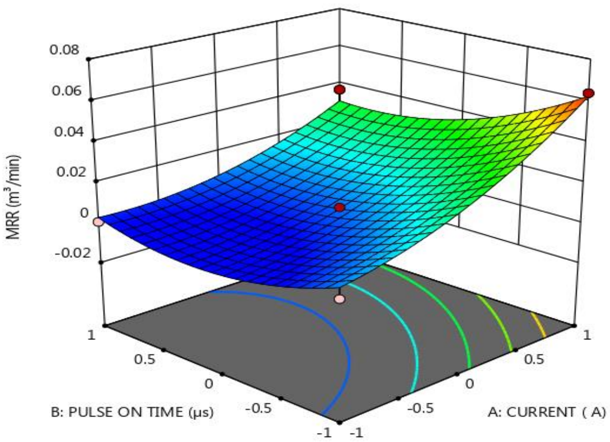

fig. 2- Combined effect of Current and pulse on time on MRR

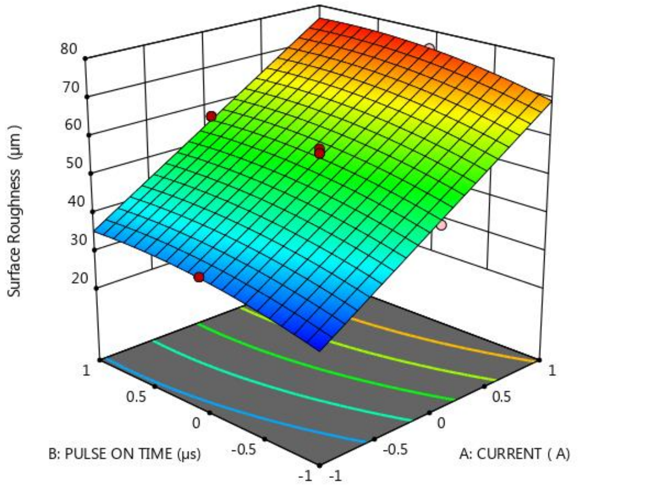

fig. 3- Combined effect of Current and Pulse on time on SR

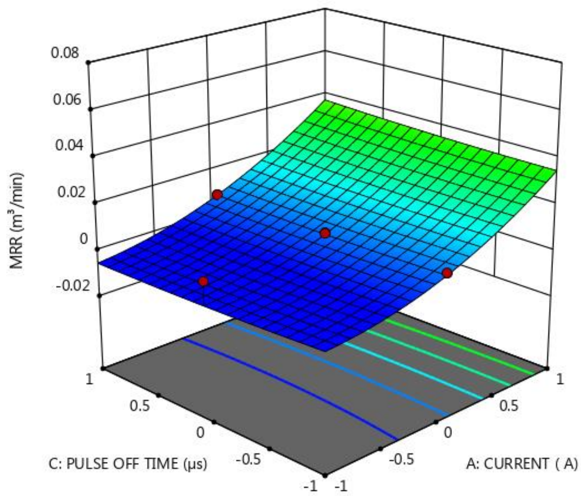

fig. 4- Combined effect of current and Pulse off time on MRR

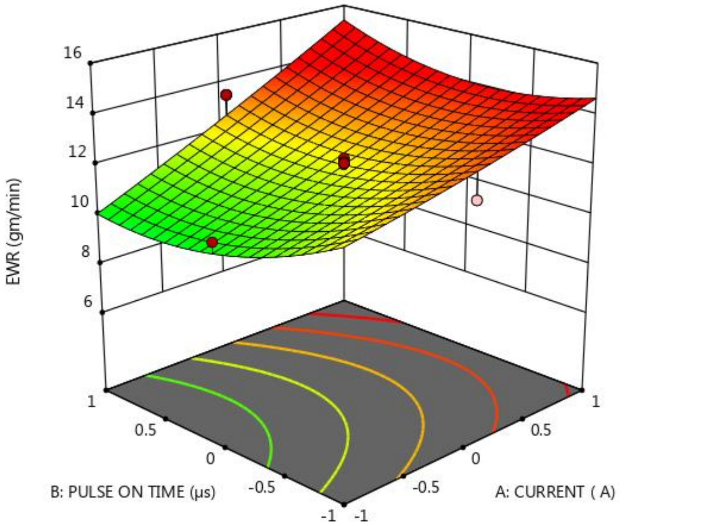

fig. 5- Combined effect of current and pulse on time on EWR

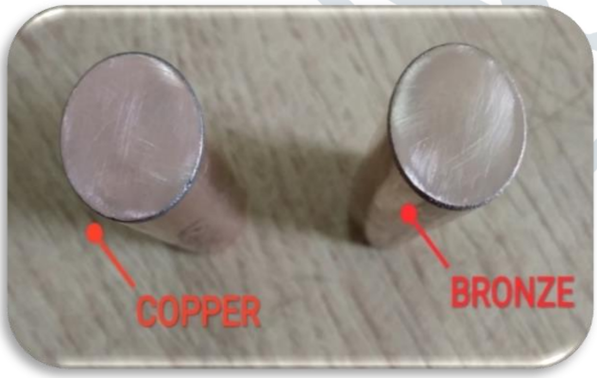

fig. 6- Machining Surface of Electrodes before machining

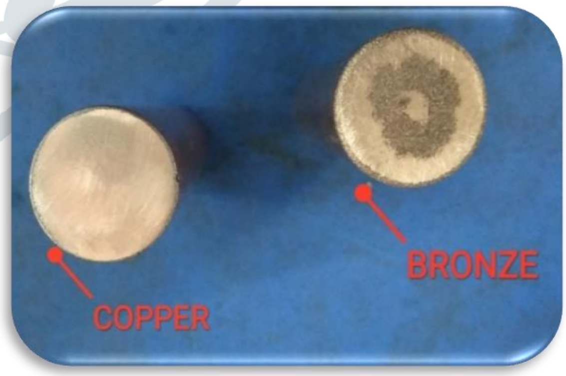

fig.7- Machining Surface of Electrodes after machining

VI CONCLUSIONS

By analyzing the results of the experiment on H13 die tool steel with copper and bronze electrode materials, the following conclusions are arrived

- Higher material removal rate obtained using Copper electrode as compared to bronze electrode.
- Copper electrode offer lower electrode wear rate as compared to Bronze electrode.

- For Bronze electrode, if flushing pressure is low then there will be deposition of electrode material on work surface and if flushing pressure is high then there will be no such metal deposition of Bronze electrode
- Therefore, for Bronze electrode at low flushing pressure surface of work piece will deteriorate and for high flushing pressure SR will be lower than Copper electrode.
- For Bronze electrode, MRR will increase as Current and Pulse on time increase but there will be increase in EWR simultaneously.
- For Copper electrode, MRR will increase as Current and Pulse on time increase and also there will be increase in EWR simultaneously but, EWR in Bronze is very higher as compared to Copper electrode.
- Current and pulse on time are most significant process parameter for electrode wear rate and material removal rate for Bronze drawn by Response surface analysis

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