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EFFECT OF EDM PARAMETERS IN OBTAINING MMR AND EWR BY MATCHING STAINLESS STEEL USING COPPER AS AN ELECTRODE

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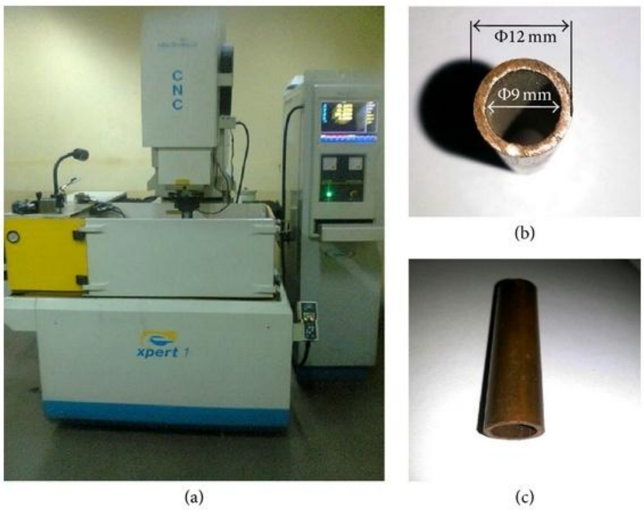
I. INTRODUCTION

Electrical discharge machining (EDM) is widely used in the production of dies. This paper describes an investigation into the optimisation of the process which uses the effect of carbon which has migrated from the dielectric to tungsten–copper electrodes. This work has led to the development of a two-stage EDM machining process where different EDM settings are used for the two stages of the process giving a significantly improved material removal rate for a given tool wear ratio. Different non-traditional machining techniques are increasingly employed in manufacturing of complex machine components. Among the non-traditional methods of machining processes, electrical discharge machining (EDM) has drawn a great deal of researchers' attention because of its broad industrial applications . EDM is widely used in machining high strength steel, tungsten carbide and controlled erosion through a series of electric sparks between the tool (electrode) and the workpiece . The thermal energy of the sparks leads to intense heat conditions on the workpiece causing melting and vaporizing of workpiece material . Due to the high temperature of the sparks, not only work material is melted and vaporized, but the electrode material is also melted and vaporized, which is known as electrode wear (EW). The EW process is quite similar to the material removal mechanism as the electrode and the workpiece are considered as a set of electrodes in EDM. Due to this wear, electrodes lose their dimensions resulting in inaccuracy of the cavities formed . During EDM, the main output parameters are the material removal rate (MRR), wear ratio (WR), EW, and job surface finish Ra . It is desirable to obtain the maximum MRR with minimal EW. Common electrode materials are graphite, brass, copper and copper-tungsten alloys . Efforts have been done to minimize EW. A metal matrix composite (ZrB_2-Cu) was developed adding different amount of Cu to get an optimum combination of wear resistance, electrical and thermal conductivity . It was reported that ZrB_2-40 wt% Cu composite shows more material removal with less EW. Research has been conducted to draw the relationship of the MRR with current Ip, gap voltage Vg, pulse on time tI, pulse off time to, etc . C.F. Hu et al. found that the MRR was enhanced acceleratively with increasing discharge current and work voltage, but increased deceleratively with tI. Manufacturing of electrodes of special composition is expensive and not always cost effective. In order to maintain the accuracy of machining, compensation of EW has been reported to be an effective technique, where EW was continuously evaluated by sensors and the compensation was made . Some researchers have tried to develop mathematical models to optimize the EW and MRR . It was reported that the MRR can be substantially increased with reduced EW using a multi-electrode discharging system. But again, a special electrode involves additional cost. In the present study the most common and easily available electrode materials like copper and brass were taken under consideration during machining of aluminum and mild steel. Wear of the electrode along the direction of movement of the electrode can be compensated by imparting additional movement of the electrode. But the wear along the cross-section of the electrode cannot be compensated. This phenomenon results in inaccuracy in the dimension of the cavities made by die-sinking technique. In the present study an analysis has been done to evaluate the EW along the cross-section of the electrode compared to the same along its movement. An analysis has also been done on the comparative performance of copper and brass as electrode materials.



II. METHODOLOGY

The Box-Behnken design (BBD) was used for planning and executing the subsequent main experimentation, as shown in Table In this study, an effort has been made to model the empirical relationship between machining parameters by using response surface methodology. The workpiece was connected to the positive polarity while the tool electrode was maintained at negative polarity. Side flushing method was employed for the dielectric fluid. A hole depth of 8 mm and diameter of 12 mm was machined throughout, for each run. The process parameters and depth of cut were programmed in the NC controlled unit. Once the experimentation was completed, the workpieces were cleaned thoroughly using acetone and the final individual weight of electrode was measured. Material removal rate was calculated by using the following formula:

MRR= V(mm^3)/t(min)

Where v is volume of material removed and t is the machining time.

Electrode and work materials The electrodes used in the present study were 70 mm long with a cross-sectional dimension of 15 mm ×15 mm. The major properties of the electrode materials are shown in Table The workpiece materials used in the present study were mild steel and aluminum.

ELECTRODE USED

Electrode materials	Thermal conductivity(W/m k)	Melting point °C	Electric restivity(ohm-cm)	Specific heat capicity(J/g-°C)
Copper	386	1.085	1.67	0.384
brass	159	940	4.8	0.38

CHEMICAL COMPOSITION	STAINLESS STEEL STANDERD	STAINLESS STEEL MATERIAL
CARBON(C)	0.035 MAX	0.016
SILICON(SI)	0.75 MAX	0.36
MANGANESE(MN)	2.00 MAX	1.165
CHROMIUM(CR)	17-20.0 MAX	18.60
SULPHUR(S)	0.03 MAX	0.002
PHOSPHORUS(P)	0.04 MAX	0.023
NICKEL(NI)	8-13.0 MAX	10.11

EWR MATERIAL

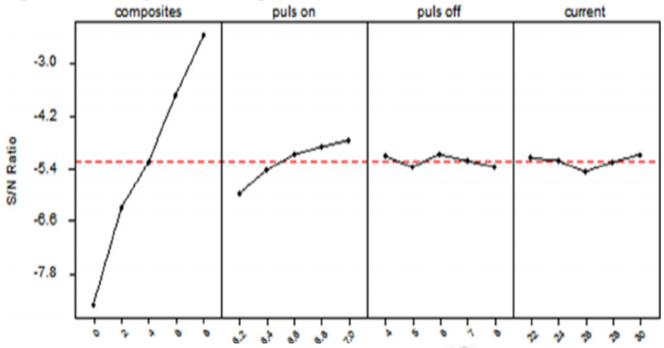
work materials	Thermal conductivity(W/m k)	Melting point °C	Electric restivity(ohm-cm)	Specific heat capicity(J/g-°C)
Stainless steel	12-45	1400-1450	169	899

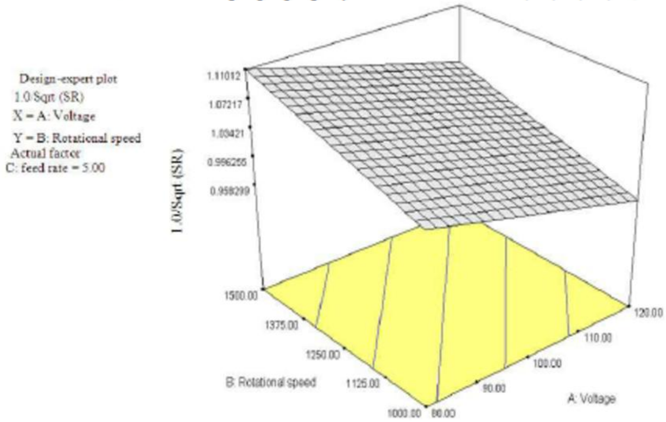
Run number	Factors			Responses		
	Pulse off time (s)	Pulse on time (s)	Pulse current (A)	Material removal rate MRR (mm^3/min)	Electrode wear rate EWR (mm^3/min)	Surface roughness SR (m)
1	22	342	5	14.6	4.7	5.32
2	7	342	5	23.37	11.6	6.3
3	11	342	20	17.25	6.4	7.22
4	22	342	42	20.96	12.9	5.25
5	11	342	20	16.85	6.7	7.45
6	19	342	25	17.55	7.2	7.57
7	5	582	25	22.99	11.8	12.12
8	5	102	20	13.53	4.5	6.42
9	12	342	25	17.86	5.8	7.23
10	16	582	45	29.03	10.2	10.16
11	16	102	5	14	3.9	4.28
12	16	582	5	26.42	13.9	9.15
13	16	102	45	16.16	5.1	5.34

III. RESULT

Serial number				MRR	EWR	SR	Desirability	Weight of		
								MRR	EWR	SR
1	579.99	11.03	5	28.03	11.99	9.18	0.87	0.8	0.1	0.1
2	503.2	4	45	26.33	8.86	9.45	0.84	0.7	0.2	0.1
3	524.61	9.49	5	26.37	11.79	8.48	0.83	0.7	0.1	0.2
4	480.40	4	45	25.41	8.50	9.18	0.83	0.6	0.3	0.1
5	448.23	4	45	24.17	7.99	8.81	0.80	0.6	0.2	0.2
6	480.14	4	45	25.41	8.49	9.18	0.83	0.6	0.1	0.3
7	442.03	4.95	45	23.90	7.8	8.75	0.82	0.5	0.4	0.1
8	413.98	4.01	45	22.91	7.45	8.43	0.80	0.5	0.3	0.2
9	433.73	11.21	5	22.42	9.60	7.41	0.79	0.5	0.2	0.3
10	385.81	5.97	5	22.57	11.37	6.82	0.80	0.5	0.1	0.4
11	383.97	6.36	45	21.85	6.89	8.13	0.82	0.4	0.5	0.1
12	357.69	7.05	45	21.01	6.48	7.86	0.81	0.4	0.4	0.2
13	100	26.88	45	17.81	7.11	4.36	0.79	0.4	0.3	0.3

The confirmatory experiments were performed to validate the optimal input parametric setting for MRR, EWR, and surface roughness. The observed experimental results for performance measures are material removal rate = 17.81 mm3/min, electrode wear rate = 6.81 mm3/min, and surface roughness = 4.36 µm. Table shows the error percentage for experimental validation of the developed models for the responses with optimal parametric setting. From the analysis, it was concluded that the error between experimental and predicted values for MRR, EWR, and surface roughness are 6.98%, 5.90%, and 7.48%, respectively. Obviously, this confirms excellent reproducibility of the experimental conclusions.





IV. CONCLUSION

In this study, the influence of significant EDM process parameters like peak current, pulse on time and pulse off time on response parameters like MRR, TWR, and SR while machining the EN 353 steel has been investigated. Experimentations were planed and conducted according to

the response surface methods. Analysis of variance (ANOVA) was applied to study the significance on performance measures. The major conclusions drawn from this study are as follows.
(1)EDM is an adequate process to machine EN 353 steel with good MRR and TWR.
(2)The MRR obtained is ranged between 14 mm3/min and 28.03 mm3/min. The maximum MRR was obtained when the parameters were set at pulse on time = 580 µs, pulse off time = 16 µs, and peak current = 42 A.
(3)The minimum EWR 3.5 mm3/min was obtained when the parameters were set at pulse on time = 100 µs, pulse off time = 28 µs, and peak current = 25 A. The interaction effect of pulse on time and pulse off time influences the most.
(4)SR while EDMing the EN 353 steel alloy is majorly influenced by all the three factors peak current, pulse on time, and pulse off time. In order to obtain better surface finish set peak current and pulse on time at low levels.
(5)The optimized values of MRR, TWR, and SR are 17.62 mm3/min, 6.47 mm3/min, and 4.54 µm, respectively, obtained at the optimum setting of parameters pulse on time, pulse off time, and peak current at 100.77 µs, 25.43 µs, and 45 A, respectively.(6)The confirmation tests showed that the error between experimental and predicted values of MRR, TWR, and SR are 6.98% and 5.90%, 7.48% and 5.66%, and 2.14% and 2.87%, respectively.

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