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Material Removal Rate and Tool Wear Ratio for Powder Mixed Dielectric Based Electric Discharge Machining

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ABSTRACT:

Electrical discharge machining (EDM) is used in die making and aerospace industries. This paper presents the performance study of the conventional EDM when used with powder mixed dielectric. Copper, graphite and mix (copper & graphite) were used. Pulse on, pulse off and current are the parameters which were varied at three levels. Copper, graphite and tungsten-copper were used as the electrode. The material removal rate and tool wear rate are assessed using design of experiments.

KEYWORDS:

Powder mixed dielectric; Material removal rate; Tool wear rate; Electric discharge machining

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1. Introduction

Electric discharge machining (EDM) is one of the most popular machining methods to manufacture dies and press tools because of its capability to produce complicated shapes and to machine very hard materials. This process enables machining of any electrical conducting material. The process removes the metal with sparks generated between the electrode tool and the work piece. The electrode tool made of copper or graphite gradually makes the cavity that is a mirror image of the shape of the tool. There is no direct contact between the electrode tool and work piece. The sparks flow through the dielectric fluid at a controlled distance [1-3]. In 1768, Sir Joseph Priestly first observed the metal erosion by spark discharges. More than hundred years elapsed before some practical use was implemented. In 1943, Lazarenko et al [4], deduced that spark discharge could be utilized for machining of new metals and complex shapes whilst investigating the wear of switch contacts.

After the investigations of Lazarenko brothers, the EDM process has attracted worldwide attention as a technique for metal machining. Since then a considerable research and development has been carried out and an improved form of EDM is used in many current applications [5]. With the addition of graphite powder in the dielectric, the metal removal rate (MRR) was increased by 60% and tool wear rate (TWR) was decreased by 15% in EDM. The wear ratio (TWR/MRR) is reduced by about 28% [6]. Additives can increase the MRR and decrease the TWR and improve the surface quality of work, especially in mid-finish machining and finish machining [7]. The silicon powder affects both the MRR and surface roughness. MRR increases with the increase in the concentration of silicon powder [8]. The 75/25 tungsten copper electrode and D2 tool steel work pieces produce optimized MRR, TWR and surface roughness [9]. Graphite electrode gave a significantly higher MRR and low electrode wear than copper electrode. The value of MRR was found to increase by 60% with positive electrode wear [10]. TiN works on the surface which exhibited improved friction and wear characteristics. Both MRR and TWR declined with an increase in pulse duration. Micro-hardness values of the order of 250Hk were achieved [11].

2. Experimental setup

The basic principle of the EDM process is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode tool and the workpiece immersed in dielectric fluid. The insulating effect of dielectric fluid is important in avoiding electrolysis of electrodes during EDM process. The spark is initiated at the point of smallest inter-electrode gap by high voltage, overcoming the strength of the dielectric thus breaking down the dielectric. Erosion of metal takes place from both electrodes (work piece and tool). After each discharge, the capacitor is recharged from DC source through a resistor, and the spark that follows is transferred to the next narrowest gap as shown in Fig. 1 [4]. The cumulative effect of a succession of sparks spread over the entire work piece surface leads to erosion, or machining to a shape. Less metal is eroded from the tool as compared to the work piece since the momentum with which positive ions strike the cathode surface is much less than the momentum with which the electron stream impinges on the anode surface. A compressive force is generated on the cathode surface by spark which helps to reduce the tool wear [2]. Experiment was conducted on an EDM model T-3822 of Victory Electromech. A schematic view of the experimental setup is shown in Fig. 2. Copper, graphite and mix (50-50% copper & graphite) powders were suspended into the commercial available kerosene oil. The size of powder particles is in the range of 250-300 mesh size. In the test, High-Carbon High-Chromium (HCHCr) and Hot Die Steel (H13) were used as the work piece materials. The chemical compositions of these materials are given in Table 1.

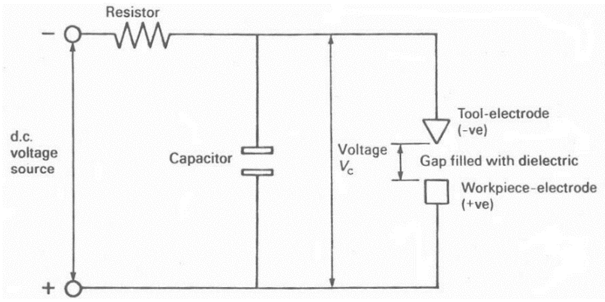

Fig. 1: Relaxation circuit

Table 1: Chemical Composition of work piece materials

% Comp.	H13	HCHCr	% Comp.	H13	HCHCr
Fe	90.6	83.5	Mo	1.1	0.05
C	0.4	1.6	Ni	0.36	0.07
Si	1	0.5	Co	0.01	0.01
Mn	0.39	0.55	Cu	0.01	0.05
P	0.03	0.03	Ti	0.01	0.02
S	0.02	0.03	V	0.3	-
Cr	5.32	13.3	W	0.1	0.02

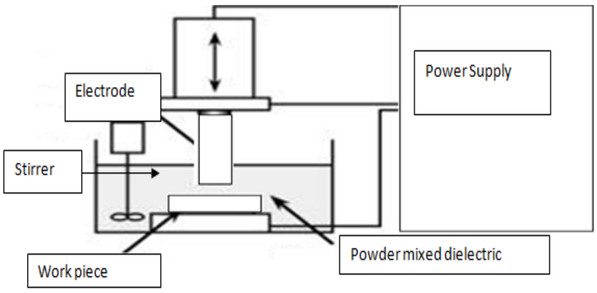

Fig. 2: Schematic of the experimental setup

Graphite, copper and tungsten-copper electrode (80-20%) of 20mm diameters were used as the electrode materials. Various process parameters are given in Table 2. The ranges of these parameters were selected on the basis of preliminary experiments. The response parameters in the present study were MRR and TWR. MRR was calculated by the weight loss method. TWR was calculated by length loss method. The fractional factorial method developed by Taguchi is a technique that allows a process to be optimised by using relatively few experiments when there are a large number of input variables. A L_{18} orthogonal array was used to identify the effect of key operating factors on the MRR and TWR. The 18 experiments were conducted as per the L_{18} orthogonal array in Table 3.

Table 2: Experimental and machining parameters

Parameter	Value
Open circuit voltage	135±5% V
Polarity	Positive
Machining time	10 minutes
Spark energy	Low
Powder concentration	10g/l
Current	2, 5, 8 A
Pulse on time	10, 50, 100µs
Pulse off time	38, 57, 85µs

Table 3: Design of experiments matrix for powder mixed EDM

Trial	Work piece	Pulse on (µs)	Current (A)	Pulse off (µs)	Electrode	Powder
1	HCHCr	10	2	38	Copper	Copper
2	HCHCr	10	5	57	Graphite	Graphite
3	HCHCr	10	8	85	W-Cu	Mix
4	HCHCr	50	2	38	Graphite	Graphite
5	HCHCr	50	5	57	W-Cu	Mix
6	HCHCr	50	8	85	Copper	Copper
7	HCHCr	100	2	57	Copper	Mix
8	HCHCr	100	5	85	Graphite	Copper
9	HCHCr	100	8	38	W-Cu	Graphite
10	H13	10	2	85	W-Cu	Graphite
11	H13	10	5	38	Copper	Mix
12	H13	10	8	57	Graphite	Copper
13	H13	50	2	57	W-Cu	Copper
14	H13	50	5	85	Copper	Graphite
15	H13	50	8	38	Graphite	Mix
16	H13	100	2	85	Graphite	Mix
17	H13	100	5	38	W-Cu	Copper
18	H13	100	8	57	Copper	Graphite

3. Results and discussions

After experimental tests on EDM, the average values of MRR and TWR for all 18 experiments are given in Table 4. For the analysis of the result, analysis of variance (ANOVA) is performed. The relationship of MRR and TWR with the current, pulse on and pulse off during machining with copper, graphite and tungsten-copper electrode in powder mixed dielectric are shown in Fig. 3 and Fig. 4 respectively. ANOVA for MRR and TWR are given in Table 5 and Table 6 respectively. At low current, MRR is low but with increase in the current MRR increases sharply. The current is more significant in the MRR. Higher MRR is observed at high current. With increase in the pulse on time, the MRR is decreased and work piece material is insignificant in MRR. With increase in the current, the TWR is also increased. TWR was decreased with an increase in pulse on and pulse off time. Electrode material is significant in TWR and work piece material is insignificant. TWR of graphite electrode is more significant when compared to the Tungsten-copper and copper electrodes.

Table 3: Design of experiments results for powder mixed EDM

Trial	MRR (mm^3/min)	TWR (mm^3/min)
1	2.98	0.011
2	11.92	5.024
3	37.26	0.616
4	0.99	1.256
5	14.03	0.136
6	14.03	0.449
7	1.36	0.112
8	15.65	3.14
9	1.61	1.57
10	4.91	0.205
11	10.89	0.449
12	34.97	3.14
13	3.89	0.068
14	9.87	0.112
15	1.43	4.71
16	3.35	0.628
17	8.5	0.068
18	11.49	0.157

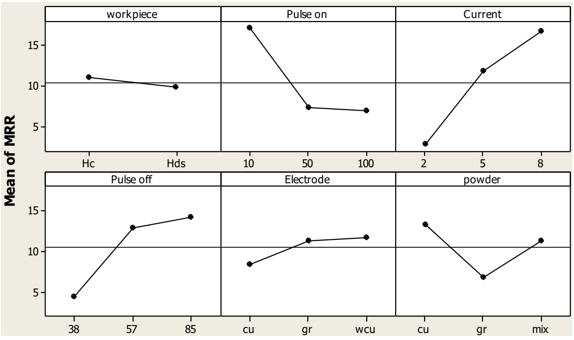

Fig. 3: Main effect plot for MRR

Table 5: Analysis of variance for MRR

Parameter	DF	SS	Variance	F	P
Work piece	1	6.16	6.160	0.10	0.766
Pulse on	2	398.17	199.085	3.15	0.116
Current	2	593.65	296.827	4.69	0.049
Pulse off	2	340.26	170.130	2.69	0.147
Electrode	2	38.88	19.441	0.31	0.746
Powder	2	135.21	67.605	1.07	0.401
Res. error	6	379.42	63.237		
Total	17	1891.76			

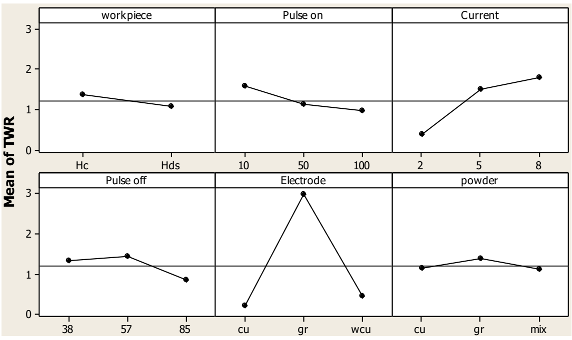

Fig. 4: Main effect plot for TWR

Table 6: Analysis of variance for TWR

Parameter	DF	SS	Variance	F	P
Work piece	1	0.4284	0.4284	0.32	0.591
Pulse on	2	1.2608	0.6304	0.47	0.645
Current	2	6.5037	3.2519	2.44	0.168
Pulse off	2	1.1655	0.5827	0.44	0.665
Electrode	2	28.3231	14.1616	10.62	0.011
Powder	2	0.2748	0.1374	0.10	0.904
Res. error	6	8.0008	1.3335		
Total	17	45.9571			

4. Conclusions

This experimental study was focused on investigating the effect of using copper, graphite and mix (copper & graphite 50-50%) and copper, graphite and tungsten-copper electrode in kerosene oil dielectric for EDM. MRR has increased with an increase of the current and pulse off but has decreased with an increase in pulse on time. MRR was more in copper mixed dielectric, followed by copper & graphite 50-50% mix and graphite. For MRR, the current was more significant, followed by the pulse on and pulse off. TWR has increased with an increase of current but has decreased with increase in pulse on time. TWR was more in graphite electrode, followed by tungsten-copper and copper electrodes. Electrode material was more significant followed by the current for TWR. Work piece material is insignificant for both the MRR and TWR.

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