Improving the Metal Removal Rate (MRR) in Electro Discharge Machining by Additives Powder

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ABSTRACT

Electro discharge machining (EDM) is one of non-traditional machining processes which is used in important application. This paper has focused on improving material removal rate by adding powders (Al_2O_3 particle size 15-35μm) and (SiO_2 particle size 20-30μm) to kerosene solution through EDM process with different ratios (0.1, 0.14, 0.18 to 0.25 g) particle size for each liter using different values of currents (8, 16 and 30 Amp) and (140 Volt) and (Toff, Ton 25 and 37 μSec),

Medium carbon steel is used as a workpeice and copper as electrode, the material removal rate (MRR). It has been found that maximum MRR was (0.2969) g/min when adding SiO_2 powder (0.25)g/l and maximum MRR was (0.2781)g/min when adding Al_2O_3 powder (0.25)g/l, the Minitab model program was used to predict the MRR which gives a good result and agreement with experiments 99%.

Keywords:- Al_2O_3 , SiO_2 , EDM , material removal rate (MRR) , Estimation of Optimum Response Characteristics for (MRR) .

INTRODUCTION

EDM is a non-conventional manufacturing process. In this process, the material is removed by erosive action of electric discharges occurring between a tool electrode and workpiece based on the fact that no tool force is generated during machining. Both workpiece and tool electrode are submerged in a solution called dielectric. The mechanical characteristics of workpiece and electrode are not a concern because the electrical energy is converted into thermal energy causing melting of the material. EDM process allows the machining of hard materials and more complex shapes which cannot be processed by other conventional methods. The EDM process is normally applied to mould and die making. Compared to conventional machining method, the material removal rate of this machining remains rather low [1]. EDM is a process of removing material in a closely controlled manner from an electrically conductive material immersed in a liquid dielectric by a series of randomly distributed discrete electrical sparks or discharges. Non-conducting materials cannot act directly on electrode to achieve EDM. In order to machine these materials with EDM, the conditions that electrical discharges can be produced on their surface must be created [2]. The process also has the advantage of being able to machine hardened tool steels. However, its low machining efficiency and poor surface finish restricted its further applications [3]

Lazerenko and the people who have invented the relax action circuit; they have invented a simple servo controller that helps to maintain the gap width between the tool and workpiece. This reduced arcing and made EDM machining more profitable [4, 5, and 6].

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Experimental Work

The experiments have been conducted using the Electric Discharge Machine, model (CM 323C+50N) (die sinking type), the polarity of the electrode has been set as negative while that of workpiece is positive. The dielectric fluid used is EDM kerosene. Then used glass pool that has dimensions (350,200,220) mm and putting it inside the container EDM machine motor for keeping the kerosene in the case of moving and making a workpiece holder from Teflon to fix the sample, the wire diameter (6mm) was used between a workpice holder and the table of EDM machine to contact the electrical to sample.

Workpiece: - medium carbon steel was used as workpieces and the chemical composition is shown in table.

Table (1) The chemical compositions of workpiece

C%	SI%	Mn%	P%	S%	Cr%	Mo%	Ni%	AL%	Co%	Cu%	V%	Fe%
0.415	0.205	0.655	0.006	0.008	0.036	0.02	0.071	0.003	0.006	0.099	0.0005	98.4

♦Chemical tests were made by the (S.I.E.R) State Company for Inspection and Engineering Rehabilitation.

♦Electrode (Copper) : The copper which is used in experiments has the following chemical composition as shown in table (2)

Table (2) chemical composition of copper

Zn%	Pb%	Sn%	P%	Mn%	Fe%	Na%	Si%	Mg%	Cr%	Al%	S%	C%	Cu%
0.057	0.001	0.005	0.002	0.0005	0.012	0.001	0.001	0.0001	0.0009	0.008	0.005	0.004	99.9

Powder:- Two types of powder used in experiments (Al_2O_3 and SiO_2) and the particle size for (Al_2O_3) was (15-30μm) and for (SiO_2) was (20-30 μm).

(MRR):- Material removal rate can be calculation as follow:-

$$MRR = \frac{Wi - Wf}{T}$$

Where wi- weight of workpiece before machining
Wf-weight of workpiece after machining.

Results and Discussions

The Effect of Current on Metal Removal Rate (MRR) by Using Pulse on Time and Pulse off sample the MRR increased, with pulse on time and pulse of time (25 µSec). Time (25 µsec).
Sample without additives:

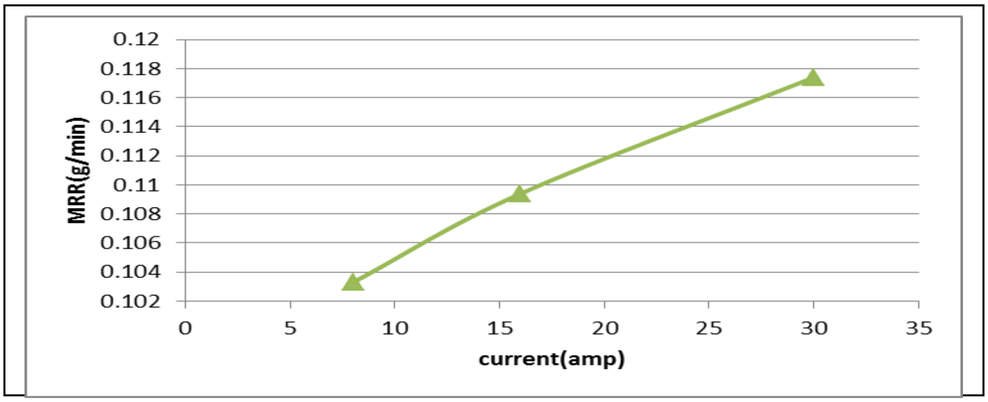

Figure (1) influence of current on MRR

Figure (1) shows the Influence of current on metal removal rate at pulse on (25 **µSec**) without additives. So When additives powder of**(** Al_2O_3 **)** As shown in Fig (2),with ratio (0.1 g/L) the MRR increase by increasing the current (8, 16 and 30) A, at pulse on time and off time 25 µSec. And by adding (0.14 g/L) Al_2O_3 noted MRR increase by increasing the current. Also by the same conditions pulse on time and off time 25 µSec, increasing the Al_2O_3 powder by ratios (0.18 and 0.25) makes it noted that the ratio (0.25) shows greater MRR than the other ratios by adding the current, and this is due to the Al_2O_3 powder effecting the MRR of the sample comparison with the sample that without additives.

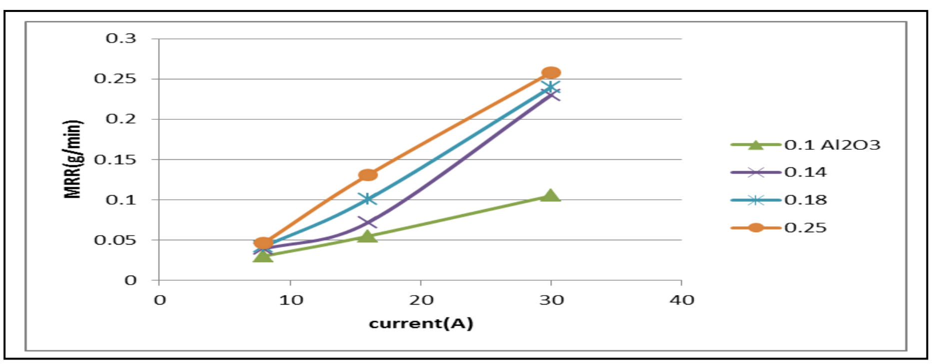

Figure (2) Influence of current on Metal Removal Rate at pulse on and off time 25 (µSec) with additives.Al2O3

and when using powder (SiO_2) As shown in Fig (3),with ratio (0.1 g/L) the MRR increasing by increase the current (8, 16 and 30) A, at pulse on time and off time 25 µSec. And by adding (0.14 g/L) SiO_2 noted MRR increase by increasing the current. Also by the same conditions pulse on time and off time 25 µSec, increased the SiO_2 powder by ratios (0.18 and 0.25) makes it noted that the ratio (0.25) shows greater MRR than the other ratios by adding the current, and this is due to the SiO_2 powder effecting on the MRR of the sample comparison with the sample that without additives and by comparison of the SiO_2 and Al_2O_3, it has been noted that the MRR in Al_2O_3 is less than in SiO_2 , that means the effect of adding Al_2O_3 in the processing of EDM is better than SiO_2 .

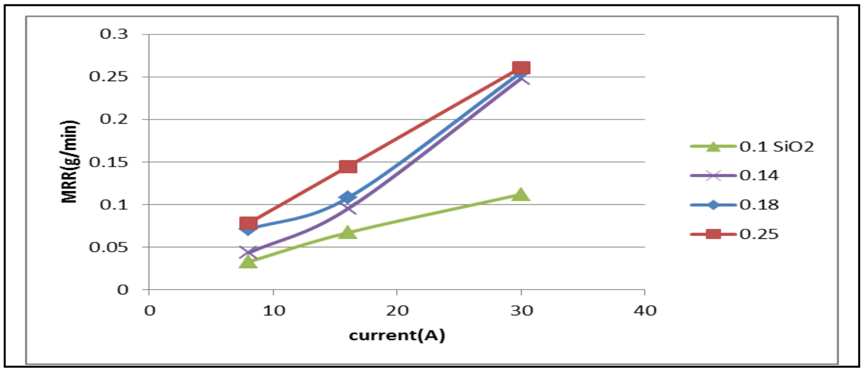

Figure (3) influence of current on metal removal rate at pulse on and off time 25 µSec with additives SiO2

The influence of current on Metal Removal Rate at pulse on and off time of 25 (µSec) with additives was used for the estimation of Optimum Response Characteristics for Material Removal Rate (MRR) Without Adding Powder.

Figure (4) shows the graph of effects Plot of machining factors, the first response (MRR) for mean, and table (3) shows the results of means. What is shown in this table, are all the selected four parameters of concentration of powder (A), current (B), pulse on (C) and pulse off (D). It is clear that the optimal parametric combination for maximum MRR is $A_1B_3C_2D_2$, i.e., at (30Amp) current , (37µsec) Ton and (37 µsec)Toff. . It is suggested that the parametric combination within the considered range as mentioned above gives greater material removal rate (MRR). Using these data, the optimum material removal rate (MRR) can be predicted using the optimum machining conditions mentioned above and according to the relation:

Predicted Mean (MRR) = $A_1 + B_3 + C_2 + D_2 - 3$(average mean)

Where: A_1= Average of (MRR) at thefirst level of concentration of powder

B_3= Average of (MRR) at the third level of current

C_2= Average of (MRR) at the second level of Ton

D_2= Average of (MRR) at the second level of Toff

From Table (3):Predicted Mean (MRR) = 0.1399+0.2020 + 0.1696 +0.1696-3 *(0.13986)

= 0.2615g/min

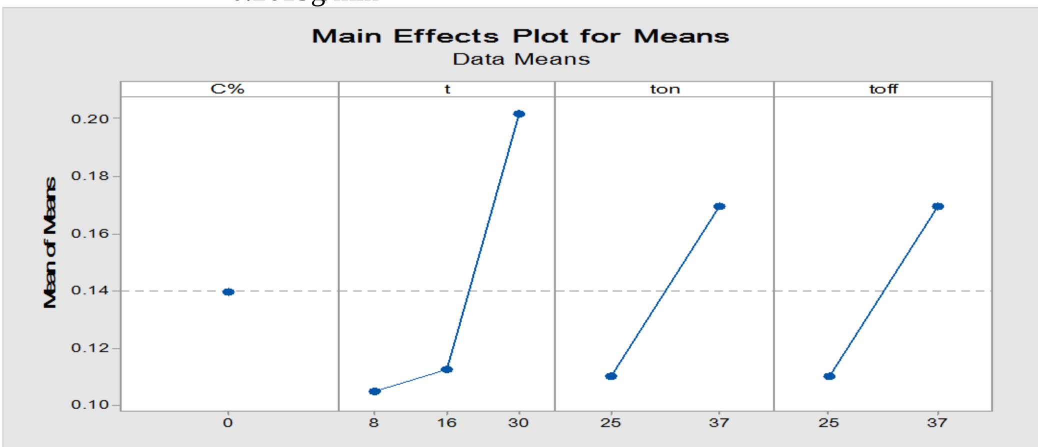

Figure (4) Main effects Plot for means for material removal rate.

Table (3):L6 TOA

NO.	C%	t	Ton	Toff	MRR1	MRR2	MRR3	SNRA	MEAN
1	0	8	25	25	0.1033	0.1033	0.1033	-19.71	0.1033
2	0	8	37	37	0.1069	0.1069	0.1069	-19.42	0.1069
3	0	16	25	25	0.1096	0.1096	0.1096	-19.20	0.1096
4	0	16	37	37	0.1154	0.1154	0.1154	-18.75	0.1154
5	0	30	25	25	0.1174	0.1174	0.1174	-18.60	0.1174
6	0	30	37	37	0.2866	0.2866	0.2866	-10.85	0.2866

Table (4) Response Table for Means of material removal rate

Level	C%	t	Ton	Toff
1	0.1399	0.1051	0.1101	0.1101
2		0.1125	0.1696	0.1696
3		0.2020		
Delta	0.0000	0.0969	0.0595	0.0595
Rank	4	1	2.5	2.5

Estimation of Optimum Response Characteristics for Material Removal Rate (MRR) with Adding Al_2O_3

Figure (4) shows the graph of effects Plot of machining factors, the first response (MRR) for mean and table (6) shows the results of means. What is shown in this table are all the selected four parameters of concentration of Al_2O_3 powder (A), current (B) , pulse on (C) and pulse off (D). It is clear that the optimal parametric combination for maximum MRR is A_4 B_3 C_2D_2, i.e., at 0.25 g/l Al_2O_3 powder, (30Amp) current, (37µsec) Ton and (37 µsec)Toff. . It is suggested that the parametric combination within the considered range as mentioned above gives greater material removal rate (MRR). Using these data, the optimum material removal rate (MRR) can be predicted using the optimum machining conditions mentioned above and according to the relation:

Predicted Mean (MRR) = A_4 +B_3 +C_2 +D_2– 3(average mean)

Where

A_4= Average of (MRR) at the fourth level of concentration of Al_2O_3 powder

B_3= Average of (MRR) at the third level of current

C_2= Average of (MRR) at the second level of Ton

D_2= Average of (MRR) at the second level of Toff

From Table (4):

Predicted Mean (MRR)=0.16488+0.22643 + 0.14757 +0.14757-3 *(0.129644)

= 0.29751675 g/min

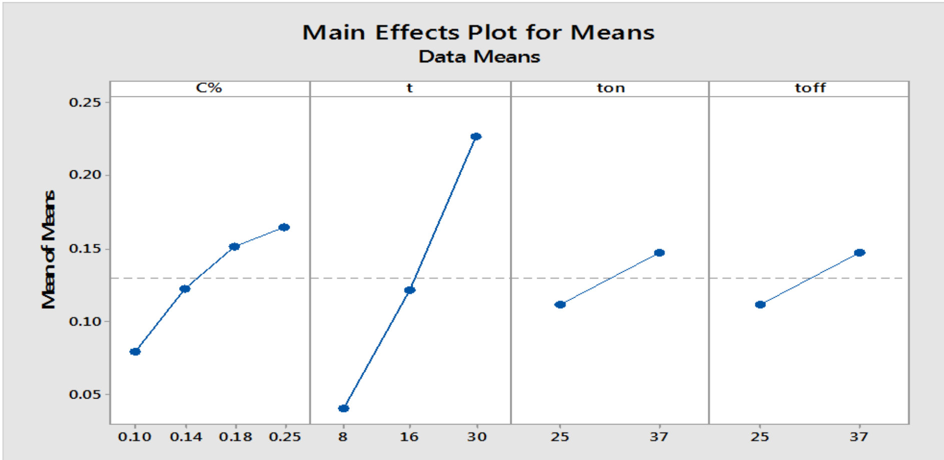

Figure (5) Main effects Plot for means for material removal rate

Table (5): L_{24} TOA

NO.	C%	t	Ton	Toff	MRR1	MRR2 2	MRR3	SNRA1	MEAN1
1	0.1	8	25	25	0.0305	0.0305	0.0305	-30.31	0.0305
2	0.14	8	25	25	0.039	0.039	0.039	-28.17	0.039
3	0.18	8	25	25	0.042	0.042	0.042	-27.53	0.042
4	0.25	8	25	25	0.0466	0.0466	0.0466	-26.63	0.0466
5	0.1	16	25	25	0.05	0.05	0.05	-26.02	0.0501
6	0.14	16	25	25	0.072	0.072	0.072	-22.85	0.072
7	0.18	16	25	25	0.1011	0.1011	0.1011	-19.90	0.1011
8	0.25	16	25	25	0.131	0.131	0.131	-17.65	0.131
9	0.1	30	25	25	0.105	0.105	0.105	-19.57	0.105
10	0.14	30	25	25	0.23	0.23	0.23	-12.76	0.230
11	0.18	30	25	25	0.238	0.238	0.238	-12.46	0.238
12	0.25	30	25	25	0.255	0.255	0.255	-11.86	0.255
13	0.1	8	37	37	0.0349	0.0349	0.0349	-29.14	0.0349
14	0.14	8	37	37	0.04	0.04	0.04	-27.95	0.0400
15	0.18	8	37	37	0.045	0.045	0.045	-26.93	0.04505
16	0.25	8	37	37	0.0486	0.0486	0.0486	-26.26	0.0486
17	0.1	16	37	37	0.0777	0.0777	0.0777	-22.19	0.0777
18	0.14	16	37	37	0.098	0.098	0.098	-20.17	0.09802
19	0.18	16	37	37	0.2133	0.2133	0.2133	-13.42	0.213296
20	0.25	16	37	37	0.23	0.23	0.23	-12.76	0.2300
21	0.1	30	37	37	0.18	0.18	0.18	-14.89	0.1802
22	0.14	30	37	37	0.2562	0.2562	0.2562	-11.82	0.2562
23	0.18	30	37	37	0.2691	0.2691	0.2691	-11.40	0.269
24	0.25	30	37	37	0.2781	0.2781	0.2781	-11.11	0.2781

Table (6): Response Table for Means of material removal rate

level	C%	t	Ton	Toff
1	0.07968	0.04083	0.11168	0.11168
2	0.12253	0.12164	0.14757	0.14757
3	0.15142	0.22643		
4	0.16488			
Delta	0.08520	0.18560	0.03589	0.03589
rank	2	1	3.5	3.5

Estimation of Optimum Response Characteristics for Material Removal Rate (MRR) with Adding SiO_2

Figure (5) shows the graph of effects Plot of machining factors, the first response (MRR) for mean and table (8) shows the results of means. What is shown in this table are all the selected four parameters of concentration of SiO_2 powder (A), current (B) , pulse on (C) and pulse off (D). It is clear that the optimal parametric combination for maximum MRR is $A_4B_3C_2D_2$, i.e., at 0.25 g/l Al_2O_3 powder, (30Amp) current , (37µsec) Ton and (37 µsec)Toff. . It is suggested that the parametric combination within the considered range as mentioned above gives greater material removal rate (MRR). Using these data , the optimum material removal rate (MRR) can be predicted using the optimum machining conditions mentioned above and according to the relation:

Predicted Mean (MRR) = $A_4 + B_3 + C_2 + D_2 - 3$(average mean)

Where

A_4= Average of (MRR) at the fourth level of concentration of SiO_2 powder

B_3= Average of (MRR) at the third level of current

C_2= Average of (MRR) at the second level of Ton

D_2= Average of (MRR) at the second level of Toff

From Table (6):

Predicted Mean(MRR) = 0.18298+0.23959+ 0.16263+0.16263-3 *(0.1433)

= 0.31788 g/min

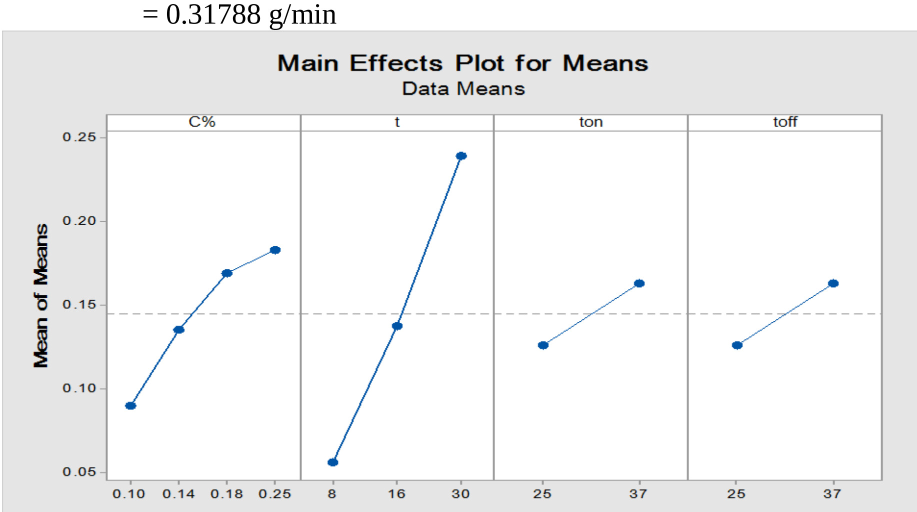

Figure (7) Main effects Plot for means for material removal rate

Table (7):L_{24}TOA

NO.	C%	t	Ton	Toff	MRR1	MRR2	MRR3	SNRA	MEAN
1	0.10	8	25	25	0.0329	0.0329	0.0329	-29.65	0.0329
2	0.14	8	25	25	0.0434	0.0434	0.0434	-27.25	0.0434
3	0.18	8	25	25	0.0710	0.0710	0.0710	-22.97	0.0710
4	0.25	8	25	25	0.0722	0.0722	0.0722	-22.82	0.0722
5	0.10	16	25	25	0.0670	0.0670	0.0670	-23.47	0.0670
6	0.14	16	25	25	0.0950	0.0950	0.0950	-20.44	0.0950
7	0.18	16	25	25	0.1078	0.1078	0.1078	-19.34	0.1078
8	0.25	16	25	25	0.1457	0.1457	0.1457	-16.73	0.1457
9	0.10	30	25	25	0.1121	0.1121	0.1121	-19.00	0.1121
10	0.14	30	25	25	0.2491	0.2491	0.2491	-12.07	0.2491
11	0.18	30	25	25	0.2561	0.2561	0.2561	-11.83	0.2561
12	0.25	30	25	25	0.2630	0.2630	0.2630	-11.60	0.2630
13	0.10	8	37	37	0.0358	0.0358	0.0358	-28.92	0.0358
14	0.14	8	37	37	0.0440	0.0440	0.0440	-27.13	0.0440
15	0.18	8	37	37	0.0741	0.0741	0.0741	-22.60	0.0741
16	0.25	8	37	37	0.0760	0.0760	0.0760	-22.38	0.0760
17	0.10	16	37	37	0.0900	0.0900	0.0900	-20.91	0.0900
18	0.14	16	37	37	0.1211	0.1211	0.1211	-18.33	0.1211
19	0.18	16	37	37	0.2301	0.2301	0.2301	-12.76	0.2301
20	0.25	16	37	37	0.2441	0.2441	0.2441	-12.24	0.2441
21	0.10	30	37	37	0.2023	0.2023	0.2023	-13.88	0.2023
22	0.14	30	37	37	0.2602	0.2602	0.2602	-11.69	0.2602
23	0.18	30	37	37	0.2770	0.2770	0.2770	-11.15	0.2770
24	0.25	30	37	37	0.2969	0.2969	0.2969	-10.54	0.2969

Table (8): Response Table for Means of material removal rate

Level	C%	t	Ton	Toff
1	0.09002	0.05617	0.12628	0.12628
2	0.13547	0.13760	0.16263	0.16263
3	0.16935	0.23959		
4	0.18298			
Delta	0.09297	0.18341	0.03636	0.03636
Rank	2	1	3.5	3.5

CONCLUSIONS

The mains conclusions which can be deduced from the present work can be summarized as follows:

1. Increasing the current (8, 16 and 30) Amp will increase the MRR.
2. Increasing the pulse on and off time increases the MRR.
3. The better ratio of Al_2O_3 to maximum MRR is (0.25g), where the (MRR=0.2781 g/min).
4. The better ratio of SiO_2 to maximum MRR is (0.25g), where the (MRR=0.2969 g/min).

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