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Letter to the Editor

A Comparative Analysis of Surface Roughness in Single and Hybrid Powder-Mixed Electric Discharge Machining Process

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Abstract

Powder-mixed electric discharge machining (PMEDM) technique overcomes the limitations of conventional (Electric Discharge Machining (EDM) technique of low Material Removal Rate (MRR) and surface finish. But the powders used does not improve all of the response variables. So hybrid PMEDM technique is developed. In hybrid PMEDM, two or more powders are mixed together in varying proportion to improve multiple responses which cannot be achieved in single PMEDM process. In this work, a comparative study is conducted between conventional single PMEDM process and hybrid powder mixed EDM process with silicon, aluminium and chromium powder. It is found that surface finish is improved in case of hybrid PMEDM.

Keywords: Powder mixed EDM, Hybrid powder-mixed EDM, Surface roughness, Response surface methodology.

1. Introduction

Electric discharge machining is a non-conventional machining technique. In this technique, the material is removed by electric spark produced between the tool and work piece interface which are separated by a certain gap distance [1]. This technique has advantage that it can machine intricate and complex shapes irrespective of its material properties such as hardness, toughness, etc, but it has low material removal rate and low surface finish. So to overcome these limitations,advancements such as powder-mixed EDM, Rotary EDM, Ultrasonic EDM, Cryogenic EDM, etc are developed [2].

In powder mixed EDM technique, various powders such as silicon, aluminium, chromium, manganese, alumina, tungsten, etc. are mixed in dielectric fluid. Silicon powder suspended in dielectric fluid improves the MRR and surface roughness than conventional EDM technique [3– 5]. Addition of chromium powder in dielectric fluid enhances the material removal rate, tool wear rate [6] and surface roughness [7]. Chromium powder also reduces the recast layer [8]. Aluminium powder increases the material removal rate and reduces tool wear rate, surface roughness, surface crack density and white layer thickness [9]. Aluminium and copper powder mixed in dielectric fluid prove that addition of metal powders improve the material removal rate, tool wear rate and surface roughness [10]. Powders like alumina prove to be improving the surface roughness of specimen [11]. Tungsten powder mixed with dielectric fluid has enhanced the material removal rate [12, 13]. The effect of SiC powder mixed in dielectric fluid reduces white layer thickness, heat flux generated and fatigue life of machined specimen [14]. From the literature survey, it is evident that powder mixed EDM process affects the response variables such as material removal rate, tool wear rate, surface integrity, etc. in a better way. But the limitation of powder-mixed EDM technique is that it improves only some of the responses due to certain properties of powder. For example, some powders improve the material removal rate but have no effect or may be in some cases, negative effects on other responses such as tool wear rate and surface integrity. So, to improve all the responses, hybrid powder mixed EDM technique is developed.

There is positive affect of aluminium and graphite powder mixed together in dielectric fluid in varying proportion on material removal rate and tool wear rate [15]. Aluminium and CNT hybrid powder mixed EDM has improved the MRR, TWR and surface roughness. It is also evident that the results of hybrid powder mixed EDM are better than single powder mixed EDM process [16]. Hence, it is clear that there is scope in hybrid powder mixed EDM process.

From the literature, it is clear that hybrid powder mixed EDM process is more effective than single powder-mixed EDM process. In the present study, comparison between single powder- mixed EDM process and hybrid powder-mixed EDM process is carried out. Powders considered for study are Silicon, Aluminium and chromium. The process parameters are current, pulse on time and powder concentration or proportion (for hybrid PMEDM) while surface roughness is the response variable.

2. Material and methods

For this present work, Elektra puls PS 50 ZNC manufactured by Electronica India Pvt. Ltd. is used for experimentation. AISI D2 steel and copper electrode is used as work piece and tool respectively. The tool diameter is 10mm. The dielectric fluid used is Ipol SEO450. Silicon, Aluminium and chromium are mixed in the dielectric fluid to enhance the responses. The duration of machining is 10 min. The process parameters considered are current, pulse on time and powder concentration or proportion. The response variables considered for experimentation is surface roughness. The

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experiments are designed based on response surface methodology [17]. Minitab 19 software is used for design of experiments [18]. Total 80 experiments were conducted i.e. 20 experiments for each powder and 20 experiments for hybrid PMEDM process. The constant parameters are duty cycle-6(from scale of 1-12), flushing pressure-0.1kg/cm2, gap voltage-50V, dielectric capacity-15 liters. The process parameters and level of experiments are as mentioned below,

Current - 6, 8 and 10A
Pulse on time - 100, 150, 200 micro-sec
Powder concentration (for conventional PMEDM) - 2, 4, 6 g/l
Powder proportion Si:Al:Cr (for hybrid PMEDM) - 1:1:1, 1:1:2, 1:2:2. (1 unit = 2g/l)

3. Theory/calculation

The main limitation of EDM process is its low material removal rate and low surface finish. In this study, surface finish is the prime objective. The surface roughness of machined surface is tested for both single PMEDM and hybrid PMEDM process. The surface roughness is tested by surface roughness tester Mitutoyo SJ210. The height of probe of roughness tester is adjusted by vernier height gauge. The probe moves over the surface and calculates the roughness of surface. The roughness is tested at 3 different locations and their average is calculated. The surface roughness test setup is as shown in figure 1.

Fig. 1. Surface roughness test setup

4. Results

The values of surface roughness for all four design of experiments are summarized in table 1.

Table 1. Surface roughness results for single and hybrid PMEDM process

Run Order	Current (A)	Pulse on time (micro- sec)	Powder conc. (g/l) or proportion	SR in Si PMEDM (microns)	SR in Al PMEDM (microns)	SR in Cr PMEDM (microns)	SR in Hybrid PMEDM (microns)
1	6	200	2 (1:1:1)	8.436	7.700	7.830	6.386
2	8	150	2 (1:1:1)	7.468	9.898	8.323	7.581
3	10	200	2 (1:1:1)	9.440	10.214	9.559	8.349
4	10	100	2 (1:1:1)	7.779	7.784	8.672	7.493
5	6	100	2 (1:1:1)	7.957	8.188	6.792	5.243
6	8	150	4 (1:1:2)	8.294	8.679	7.562	7.674
7	8	100	4 (1:1:2)	7.458	7.979	7.774	8.815
8	8	150	4 (1:1:2)	8.778	8.965	7.454	7.478
9	10	150	4 (1:1:2)	9.182	10.253	9.530	8.417
10	8	150	4 (1:1:2)	8.556	8.843	7.692	6.547
11	6	150	4 (1:1:2)	7.223	6.896	5.875	6.202
12	8	150	4 (1:1:2)	8.012	9.003	8.202	6.681
13	6	150	4 (1:1:2)	9.082	10.595	7.431	6.427
14	8	150	4 (1:1:2)	8.991	9.199	8.717	7.348
15	8	150	4 (1:1:2)	8.643	9.746	8.189	7.768
16	10	200	6 (1:2:2)	9.428	10.03	9.272	8.61
17	6	100	6 (1:2:2)	7.807	7.683	6.258	5.389
18	8	150	6 (1:2:2)	8.104	9.224	9.843	7.362
19	6	200	6 (1:2:2)	6.970	8.061	6.158	7.184
20	10	100	6 (1:2:2)	9.054	7.139	8.818	8.685
Minimum Surface roughness				6.970	6.896	5.875	5.243
Average Surface roughness				8.333	8.804	7.998	7.282

From table 1, it is clear that surface roughness for single powder mixed EDM is higher than hybrid powder mixed EDM process. The minimum surface roughness which is achieved by hybrid powder-mixed EDM process is 5.243 microns which is 0.632 microns less than that of chromium powder mixed EDM process. The average surface roughness for hybrid powder mixed EDM process is 7.282 microns which is 0.716 microns less than chromium powder mixed EDM process. The results are summarized in figure 2.

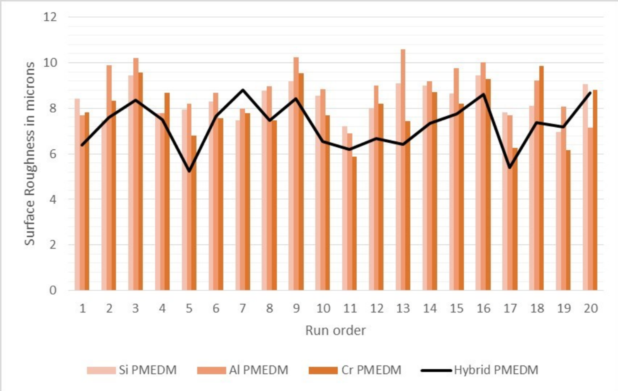

Fig. 2. Surface roughness results for single and hybrid powder mixed EDM summarized

From figure 2, it is clear that for most of the experiments, surface roughness is lower in hybrid powder mixed EDM process than single powder mixed EDM process. The analysis of variance of hybrid powder mixed EDM process is as shown in table 2.

From analysis of variance, it is clear that current and pulse on time are most significant parameters. Powder proportion has 69% significance which is high. Therefore, powder proportion also affects the surface roughness.

The main effect plot is as shown in figure 3. From the main effect plot, it can be inferred that surface roughness is minimum at current of 6A, pulse on time of 100micro-sec and powder proportion of 1:1:1.

Table 2. Analysis of variance for hybrid powder mixed EDM process

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Significance %
Model	9	16.2857	1.8095	4.36	0.015	98.5
Linear	3	13.9346	4.6449	11.20	0.002	99.8
Current	1	12.3167	12.3167	29.69	0.000	100
Pulse on time	1	1.045	1.045	2.52	0.144	85.6
Powder Prop.	1	0.4744	0.4744	1.14	0.310	69.0
Square	3	1.4651	0.4884	1.18	0.367	63.3
Current*Current	1	0.6481	0.6481	1.56	0.240	76
Pulse on time*Pulse on time	1	1.0139	1.0139	2.44	0.149	85.1
Powder Prop.*Powder Prop.	1	0.6583	0.6583	1.59	0.236	76.4
Interaction	3	0.6237	0.2079	0.50	0.690	31.0
Current*Pulse on time	1	0.5816	0.5816	1.40	0.264	73.6
Current*Powder Prop.	1	0.0324	0.0324	0.08	0.786	21.4
Pulse on time*Powder Prop.	1	0.0097	0.0097	0.02	0.881	11.9
Error	10	4.1483	0.4148			
Lack-of-Fit	4	2.7953	0.6988	3.10	0.105	
Pure Error	6	1.353	0.2255			
Total	19	20.434				

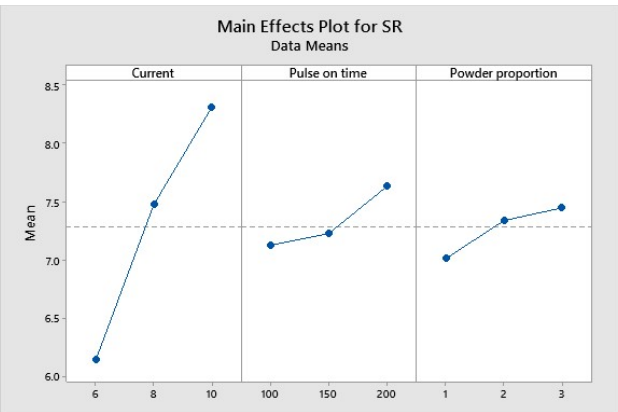

Fig. 3. Main effect plot for hybrid powder mixed EDM process

5. Conclusions

From the results, it is evident that

1. There is improvement in surface finish in case of hybrid powder mixed EDM process than single powder mixed EDM process.
2. The minimum surface roughness for hybrid PMEDM process is 5.243 microns and average surface roughness is 7.282 microns.
3. The minimum surface roughness of silicon, aluminium and chromium is 6.97, 6.896 and 5.875 microns respectively which is higher than hybrid PMEDM process.
4. The average surface roughness of silicon, aluminium and chromium is 8.333, 8.804 and 7.998 microns respectively which is higher than hybrid PMEDM process.

5. Current and pulse on time are the most significant parameters in hybrid powder mixed EDM process. Powder proportion is also an influential parameter.
6. Surface finish is superior at current of 6A, pulse on time of 100micro-sec and powder proportion of 1:1:1.

Hence, hybrid powder mixed EDM process has future scope in development of conventional EDM and PMEDM process to improve the response variables such as surface roughness, material removal rate, etc. Multiple combinations of powder can be studied to improve the responses further.

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