Experimental Investigations into Powder-Mixed Electrical Discharge Machining (PMEDM) of HCHCr D2 Die Steel

R. Shinde[1], N. Patil[2*], D.Raut[3], R. Pawade[4], P. Brahmankar[5]

[1]Assistant Professor, Deogiri Institute of Engineering & Management Studies, Aurangabad, India
[2]Professor,Marathwada Institute of Technology, Aurangabad, India
[3] Professor,Veermata Jijabai Technological Institute, Mumbai (M.S.), India
[4]Associate Professor,[5]Professor,Dr. Babasaheb Ambedkar Technological University, Lonere, India
{nilesh.patil@mit.asia}

Abstract: The purpose of this paper is to present an experimental work attempting to model and optimize the influencing process parameters involved in powder-mixed electrical discharge machining (PMEDM). Looking at available literature it is observed that a lot of work can be done in the field of electric discharge machining related to surface integrity. In this work Aluminum, Silicon and Silicon Carbide fine abrasive powders with particle concentration of 2 gm /l and size of 44 µm were added into the SEO25 (spark erosion oil) dielectric liquid of electrical discharge machine. The experiments were carried out on experimental set up developed in laboratory. HCHCr D2 die steel and copper was used as work piece and tool electrode materials, respectively. Response surface methodology (RSM), employing a face-centered central composite design for three design variables such as peak current *(Ip)*, pulse on-time *(Ton)*, and powder material was used to assess the process performance. Suitable mathematical models for the response outputs were obtained.

Keywords: ***PMEDM, Material removal rate, Tool wear rate, Surface roughness, RSM***

1 Introduction

Amongst the non-traditional machining processes, electrical discharge machining (EDM) finding increased applications in tool and dies making industry because of its ability to produce geometrically complex shapes and capability to machine extremely harder, electrically conductive materials. Still, the disadvantages like high time consuming machining process and poor surface finish limits its use in the industry. Researchers have been trying to explore the different ways to improve the EDM process since long time and Powder Mixed Electrical Discharge Machining (PMEDM) is one of such attempt to enhance process capabilities to overcome the disadvantages.

PMEDM has a different machining mechanism from the conventional EDM [1]. The electric field is created by applying voltage between two electrodes. The desired powder is suspended into dielectric fluid. The spark gap is filled up with these additive particles resulting increased gap distance between tool and the workpiece from 25–50 to 50–150 µm [2-4]. Energized powder particles in the spark gap are accelerated by the electric field and act like conductors forming chains which bridge the gap between the tool electrode and the workpiece leading to an early explosion helps enhancing the ignition process causing faster erosion from the work piece surface [3].

1.1Background

It has been reported by many researchers in recent studies that addition of powder particles such as Al, Si, C, SiC, Al_2O_3, Ni, Ti, Cr and Cu powders (size smaller than 100 µm) significantly affects the performance of EDM process [5]. Tzeng and Chen used aluminium, chromium, copper, and silicon carbide powders for machining SKD-11 and found that the best surface finish was obtained with smallest particles size i.e, (70–80µm) [6]. Kung and Chaing reported that MRR increases, while TWR decreases with increase in powder concentration. Both MRR and TWR apparently increase with increase in pulse on time and discharge current.

B. Iyer, S. Nalbalwar and R. Pawade (Eds.)
ICCASP/ICMMD-2016. Advances in Intelligent Systems Research.
Vol. 137, Pp. 298-303.
© 2017. The authors - Published by Atlantis Press
This is an open access article under the CC BY-NC license (http://creativecommons.org/licens)es/by-nc/4.0/).

The experiments were performed using Al powder suspended in mineral oil as dielectric with 94WC-6Co work material and copper as tool electrode [7]. Amandeep Singh presented a review on recent advancement in EDM. He concluded that additive powder in electrolyte can lead to increase in MRR and decreased TWR [8]. Based on the literature the most promising results were found with Al, Si and SiC. Hence these powders were used in EDM for experimental purpose.

2 Experimentation

The experiments were performed on ZNC, Electronica EDM machine. Dielectric used was SEO25. A separate experimental set up was designed. For a set of experiment, different powders i.e. Al, Si and SiC in ration of 2g/l were mixed in a dielectric. The work piece material used in this study is HCHCr D2 die steel (Comparable standards: AISI D2).

Table 1 Process Parameters and their Levels

Sr. No.	Machining Parameters	Symbol	SI Unit	Levels				
				-2	-1	0	1	2
01	Peak Current	Ip	A	1	6	11	16	21
02	Pulse on Time	Ton	µs	100	200	300	400	500
03	Powder	Powder	-	Al	Al	Si	SiC	SiC

In this work, total 20 experiments were conducted at the stipulated conditions. The experimental plans were designed on the basis of the central composite design (CCD) technique of RSM. Table 2 shows the responses observed by performing the experiments and depending upon responses observed effect of specific input parameter on the response parameter was studied.

3 Results and Discussion

For the analysis of the results ANOVA is employed to identify significant parameters. In addition, response surface model have been developed and presented for material removal rate, tool wear rate and surface roughness. The adequacies of the model are given in Table 3. The Model F-value, R-Squared and Adj R-Squared value implies that model is significant. This model can be used to navigate the design space.

Table 2 Experimental Observations

Experiment No.	Ip (A)	Ton (µs)	Powder	MRR (mm^3/min.)	TWR (mm^3/min.)	SR Ra(µm)
1	06	200	Al	0.959	0.128	3.19
2	16	200	Al	1.226	0.093	3.88
3	06	400	Al	2.102	0.27	3.17
4	16	400	Al	2.803	0.319	4.23
5	06	200	SiC	0.942	0.094	3.08
6	16	200	SiC	1.143	0.084	4.16
7	06	400	SiC	1.839	0.171	2.79
8	16	400	SiC	2.26	0.193	4.09
9	01	300	Si	0.387	0.056	3.25
10	21	300	Si	1.132	0.0861	5.05
11	11	100	Si	1.032	0.067	3.5
12	11	500	Si	3.09	0.329	3.16
13	11	300	Al	2.871	0.409	3.30
14	11	300	SiC	2.453	0.265	3.22

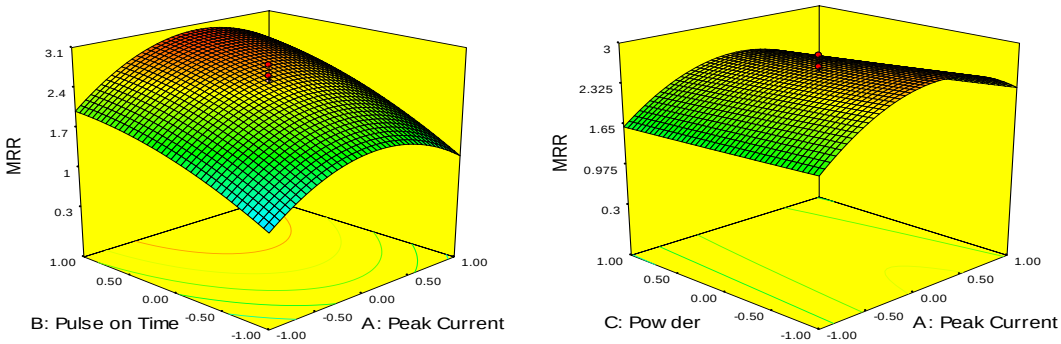
15	11	300	Si	2.616	0.325	2.74
16	11	300	Si	2.453	0.258	2.81
17	11	300	Si	2.803	0.361	2.67
18	11	300	Si	2.505	0.276	2.78
19	11	300	Si	2.45	0.267	2.90
20	11	300	Si	2.616	0.312	2.77

Table 3 Adequacy of the models

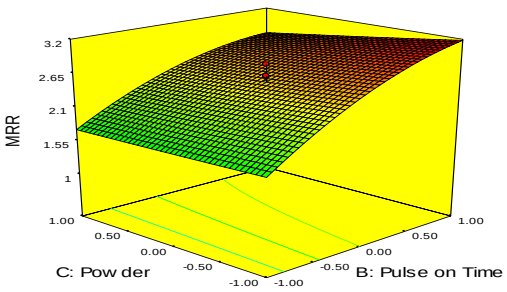
Response Parameters	**F Value**	**R-Squared**	**Adj R-Squared**
MRR	94.7701	0.988412	0.977982
TWR	22.4464	0.952834	0.910385
SR	114.518	0.990391	0.981742

3.1 The Influence of Process Parameters on Performance Measures

In this section the effect of controlling parameters such as peak current (Ip) , Pulse on time (Ton), and powder properties on material removal rate, tool wear rate and surface roughness are presented on the basis of twenty sucessful runs carried out for the specific combination of the input parametes and their levels.



(a) (b)

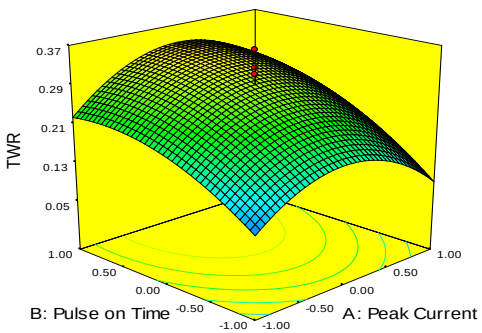


(c)

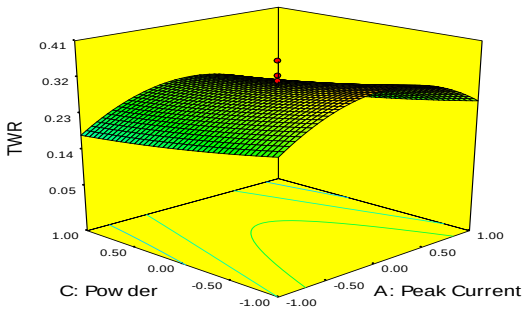
Fig. 1. Surface Plot for MRR

From the figure 1, it can be seen that at lowest range of peak current 1A, MRR found to be low, increasing gradually up to mid range of 11A, and decreased slowly with further increase in peak current. Whereas in case of pulse on time the lowest MRR is observed at lowest values of 100µs increased consistently up to 500µs, hence, maximum MRR is obtained at high peak current of 11A and highest pulse on time 500µs. The effect of powder type and peak current on MRR is shown in Figure 1(B) At range of peak current 11A-16A, MRR found to be best and decreased with increase in peak current, to be found lowest at decreased value of 1A, Whereas Al found to be producing highest MRR of 2.871mm^3/min. at peak current of 11A and Si with the value of 1A gives the lowest results. Now figure 1(C) reveals the estimated response surface of interaction between powder and pulse on time for MRR. It increases with increase in pulse on time applicable to all three powders. It also shows that pulse on time and powder combination have significant effect on MRR specially in case of Al producing maximum MRR at highest pulse on time value 500µs and minimum MRR at pulse on time value of 100µs.

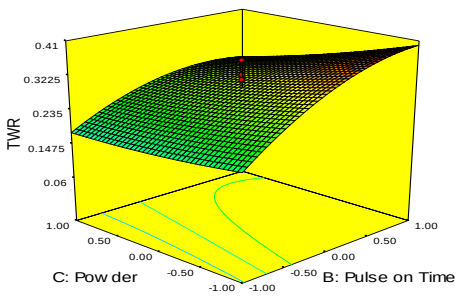
Figure 2 shows the estimated response surface for TWR in relation to peak current and pulse on time. At lowest range of peak current 1A, found to be lowest increased gradually up to mid range of 11A, and decreased slowly with further increase in peak current. Whereas, in case of pulse on time the lowest TWR is observed at lowest values of 100µs increased consistently till highest value of 500µs. Hence, maximum TWR can be obtained at high peak current of 11A and highest pulse on time 500µs.



(a)



(b)



(c)

Fig. 2. Surface plot for TWR

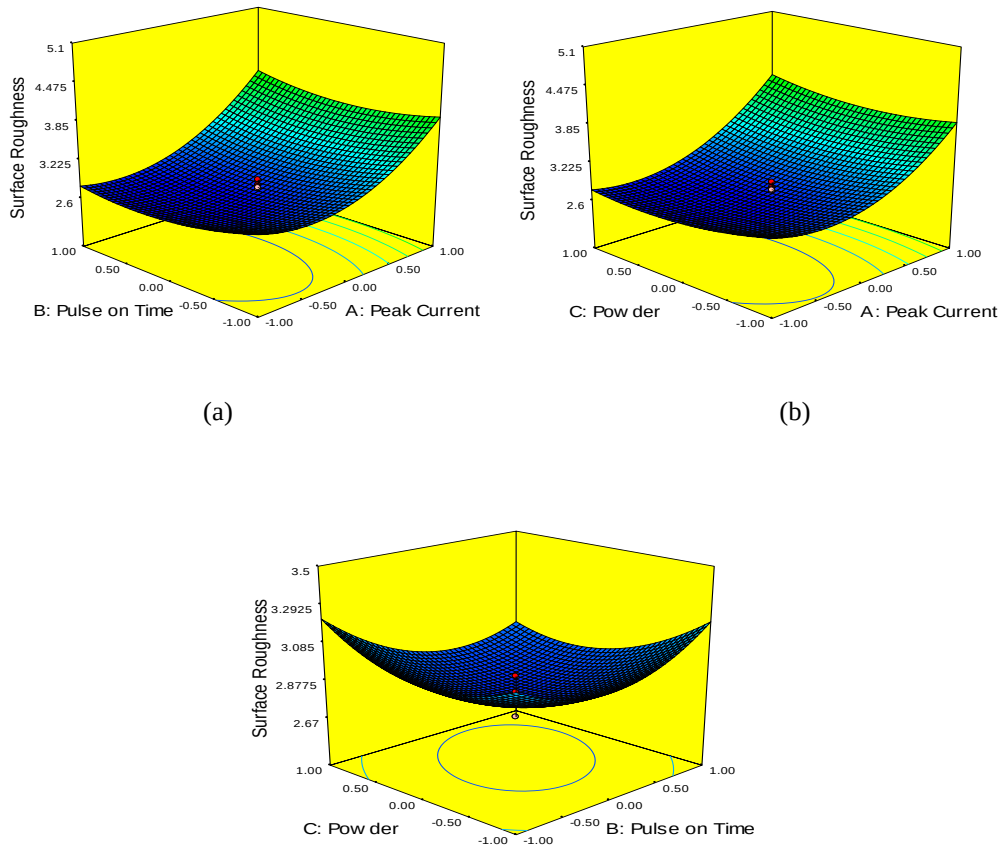


Fig. 3. Surface plot for surface roughness

Figure 3 shows that increasing peak current increases the surface roughness as increase in peak current increases the discharge energy and the impulsive force there by removing more molten material. This generates deep and larger discharge craters which increases the roughness of the surface. Higher roughness found at high peak current of 21A combining with highest and lowest values of pulse on time 100µs and 500µs. With low peak current the best surface finish is obtainable at the mid range level of peak current 6A to 11 A and pulse on time 200µs - 300µs. Al produces high surface roughness followed by Sic and the Si. The effect of powder type and peak current is shown in Figure 3(B). The highest roughness found at high peak current of 21A. with low peak current the best surface finish is obtainable at the mid range level of peak current 6A to 11 A and Al produce high surface roughness followed by Sic. Si produce the best surface finish than other two powders. In Figure 3(C) the estimated response surface of interaction between powder and pulse on time for Surface Roughness is shown. It can be seen that SR increases with higher and lower range of pulse on time in case of Al powder. Whereas in case of Si, SR found to be high at lowest values of pulse on decreases gradually up to certain point and again start increasing with increase in pulse on time. SiC gives the best surface finish as pulse on time increases.

4 Conclusions

- The significant improvement had been observed due to addition of powder. Material removal rate is higher with Al as an additive in comparison to that of Si and Sic. While comparing all three powders (Al, Si, SiC), the better result were found with the Si powder.
- Surface roughness was mainly affected by the current and pulse on time. At higher value of current causes the more surface roughness.
- Of all the machining parameters investigated, current was found to be the most significant factor. Higher current produced higher MRR, TWR and SR.
- The significant results of confirmation experiments have confirmed the validity of the used Response surface methodology for optimizing the machining parameters.

References

[1]. W.S. Zhao, Q.G. Meng, Z.L. Wang, "The application of research on powder mixed EDM in rough machining", J. Mater. Process. Technol.129 (2002) 30–33.
[2]. K. Furutani, A. Saneto, H. Takezawa, N. Mohri, H. Miyake, "Accertation of titanium carbide by electrical discharge machining with powder suspended in working fluid", Prec. Eng. 25 (2001) 138–144.
[3]. S. Singh and A. Bhardwaj, "Review to EDM by using water and powder-mixed dielectric fluid", Journal of Minerals & Materials Characterization & Engineering, 10(2) (2011) 199-230.
[4]. H.K. Kansal, Sehijpal Singh, "Technology and research developments in powder mixed electric discharge machining (PMEDM)", Journal of Materials Processing Technology 184 (2007) 32–41.
[5]. Bekir Ozerkan, Can Cogun, "Effect of PMEDM Performance in EDM", G.U. Journal of Science,18(2):211-228(2005)
[6]. Tzeng Y.F., Chen F.C.,"Investigation into some surface characteristics of electrical discharge machined SKD-11 using powder-suspension dielectric oil", Journal of Materials Processing Technology, (2005) *170* (1–2), 385–391.
[7]. Kung K.Y., Horng J.T., Chiang K.T., "Material removal rate and electrode wear ratio study on the powder mixed electrical discharge machining of cobalt-bonded tungsten carbide", International Journal of Advanced Manufacturing Technology, (2009) *40*, 95–104.
[8]. Amandeep singh, Neel kanth grover, Rakesh Sharma, "Recent Advancement in Electric Discharge Machining, A- Review", International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.5 (2012) pp 3815-382.