Effect of Silicon Powder Mixed EDM on Surface Roughness of Al6063 Aluminium Alloy

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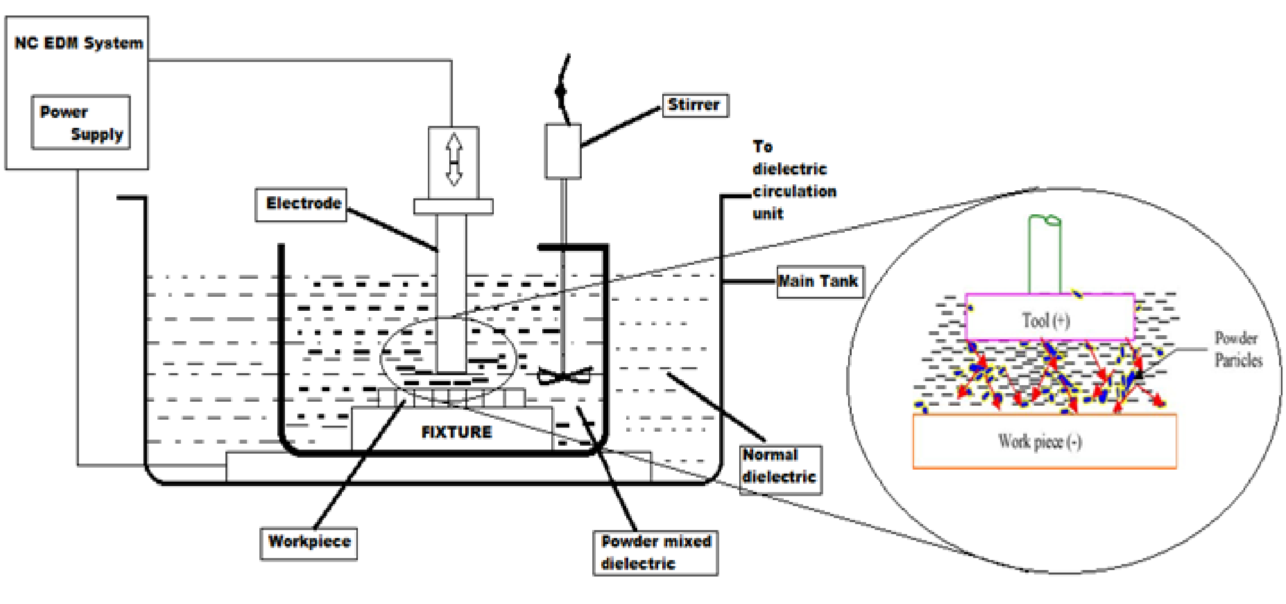
Abstract

In this paper, the effect of silicon powder mixing into the dielectric fluid of EDM on Surface roughness of Al6063 aluminium alloy has been studied. Three process parameters, namely peak current, pulse on time, concentration of powder has been considered. The process performance is measured in terms of surface roughness (SR). The research outcome will identify the important parameters and their effect on SR of Al6063 alloy in the presence of suspended silicon powder in an EDM oil dielectric. The study indicated that all the selected parameters have a significant effect on the mean and variation in SR (S/N ratio). A well-known Taguchi methodology is applied to optimize the SR. The confirmation runs showed that the setting of peak current at a low level (1 A), pulse-on time at a low level (10 μs), powder concentration at a medium level (4 g/l) produced best surface finish from Al6063 alloy surfaces when machined by silicon powder mixed EDM.
Keywords: Silicon Powder, PMEDM, Surface Roughness (SR), Optimization, Taguchi Method

I. INTRODUCTION

Electrical discharge machining (EDM) is a non-conventional machining process used to manufacture intricate profiles, complex shapes, process hard materials that are extremely difficult to machine by conventional machining processes. It can be successfully employed to machine electrically conductive parts regardless of their hardness and brittleness. In spite of remarkable process capabilities, limitations such as less material removal rate and poor surface quality are associated with EDM. In the recent past, powder mixed EDM (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the capabilities of EDM [1]. In this process, a suitable material in fine powder form is mixed into the dielectric fluid of EDM. The spark gap is filled up with additive particles. The added powder significantly affects the performance of EDM process. The electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap distance between the tool electrode and workpiece. As a result, the process becomes more stable, thereby improving surface finish.

II. TECHNOLOGY AND PROCESS MECHANISM OF PMEDM



(a) (b)

Fig. 1: (a, b) Schematic diagram of machining set-up and principle of powder-mixed EDM

In powder mixed electric discharge machining (PMEDM) process, the experimental unit consists of a transparent bath similar to container, called machining tank. It is placed in the work tank EDM and the machining is performed in this container. For the better circulation of the powder mixed dielectric, a stirring system is engaged. For regular reuse of powder in the dielectric fluid, a modified circulation system (Fig.1 (a)) is used. For holding the work piece, a work piece fixture assembly is placed in it. The machining tank is filled up with dielectric fluid. A stirring system was included to avoid particle settling. The pump and the stirrer assembly are placed in the same tank in which machining is to be done.

The minimum distance (10 in.) between powder mixed dielectric suction point and nozzle outlet should kept for better suspension of powder in the discharge gap.

Powder particles fill up the spark gap. During the process, when the voltage of 80–320 V is applied between the electrode and the work piece facing each other with a gap of 25–50 m [1], an electric field in the range of 105–107 V/m is produced. Under the influence of high electric potential, the powder particles get energized and behave in a zigzag manner (Fig. 1(b)). These charged particles are accelerated by the electric field and serve as conductors. The conductive particles help breakdown in the gap and increase the spark gap between tool and the work-piece. In the region of sparking area, the particles come close to each other and organize themselves in the form of chain like structures between both the electrodes. In the direction of flow of current, there is occurring of interlocking between the different powder particles. The chain arrangement helps in bridging the discharge gap between both the electrodes. Because of bridging effect, the insulating strength of the dielectric fluid decreases. As process goes on short circuit takes place, which causes early explosion in the gap. Therefore, a series discharge starts below the electrode area. The faster sparking within a discharge takes place causing faster erosion from the work piece surface and hence the material removal rate (MRR) increases. Simultaneously, the adding of powder modifies the plasma channel. The plasma channel becomes enlarged and opened [2]. The sparking is evenly distributed among the powder particles, therefore electric density of the spark decreases. Due to uniform distribution of sparking among the powder particles, shallow craters are formed on the work piece surface. This results in improvement of surface finish.

III. LITERATURE REVIEW

Kobayashi et al. [3] investigated the effects of suspended powder in dielectric fluid on surface roughness. It was reported that the surface finish of SKD-61 material is improved with the use of silicon powder.

Narumiya et al. [4] that under specific working conditions aluminium and graphite powders yield a better surface finish than the silicon powder. The best results (Ra less than 2 μm) are obtained for aluminium and graphite powder particles having diameters less than 15 μm and concentration ranges from 2 to 15 g/l.

Mohri, Saito, and Higash [5] reported the effect of silicon powder addition into dielectric fluid on the surface finish of H-13 die steel. The fine and corrosion-resistant surfaces having roughness of the order of 2 μm were produced.

Pecas and Henriques [6] investigated the influence of silicon powder mixed dielectric on conventional EDM. The surface quality is assessed through quality surface indicators and process time measurements over a set of different processing areas. The results show that by the addition of 2 g/l silicon powder, the operating time and surface roughness decrease. The average surface roughness depends on machining area and machining time. The surface roughness varies from 0.09 to 0.57 μm for the area range of 1 cm2 to 64 cm2.

Wong et al. [7] studied the ‘‘near-mirror-finish’’ phenomenon in EDM using fine powder (silicon, graphite, molybdenum, aluminium, and silicon carbide) mixed dielectric. It was shown that there is great influence of the powder and work material properties on material removal rate, tool wear rate, and surface roughness. Aluminium powder has been reported to give a mirror finish on a SKH-51 workpiece but failed to produce a mirror-like finish on surface of SKH-54 material.

W.S Zhao et al [8] investigated that PMEDM improves the machining efficiency and surface roughness by selecting proper discharging parameters. He observed PMEDM makes discharge breakdown easier and enlarges the discharge gap which widens the discharge passage, because of this there is loss of discharge energy in the gaps and reduction of ejecting force on melted material, surface roughness becomes lower. Further, when peak current increases the surface roughness becomes lower.

Ming and He [9] reported that the additives (conductive and inorganic oxide particles) increase the MR, decrease the tool wear rate, and improve the surface quality of the workpiece quite effectively, especially in mid-finish machining and finish machining phases.

Uno and Okada [10] investigated the effect of silicon powder mixing on the surface generation mechanism. The EDM with silicon powder mixed fluid produced glossier surfaces as compared to those produced by conventional EDM with kerosene fluid. It was argued that EDM with silicon powder mixed fluid led to smaller undulation of a crater because the impact force acting on the workpiece is smaller. This results in the stable machining without a short-circuit between the electrode and the workpiece.

K. M. Patel et al [11] investigated the influence of parametric setting on machining performance during EDM of Al2O3/SiCw/TiC ceramic composite. He observed that pulse on time influences the SR more predominantly than other factors due the fact that any increase in the pulse-on time increases the plasma channel diameter that reduces both energy density and impulsive force. The melted debris cannot be removed completely due to reduction in impulsive force and forms an apparent globule like recasted layer to degrade SR. Furthermore, the SR increases first and then decreases with the increase in the duty cycle due to the fact that the gap voltage does not affect the quality of the surface.

IV. EXPERIMENTAL DESIGN

A simple, efficient, and systematic Taguchi method was used for the design of the experiment. The Taguchi method uses signal-to-noise (S/N) ratio to quantify the variation in data. Peak current, pulse on time, powder concentration is the process parameters selected for this study. The ranges of these parameters were selected on the basis of preliminary experiments conducted by using the 'change one variable at a time approach'. The range of process parameters, their levels, and symbols are given in Table 3. The experiments were conducted according to the trial conditions as specified in standard Taguchi OA L9. The selected response characteristic in the present work is surface roughness and will be considered as 'lower the best.'

Table 1:
Chemical Composition of Al6063 alloy

Workpiece Material	Chemical Composition (Wt %)								
	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Al6063 alloy	Max 97.5	Max 0.1	Max 0.1	Max 0.35	0.45-0.90	Max 0.1	0.2-0.6	Max 0.1	Max 0.1

Table 2:
Physical Properties ofAl6063 alloy

Property	Value
Density	2.7 g/cm3
Melting Point	580°C
Modulus of Elasticity	70-80 GPa
Electrical Resistivity	5×10^{-6} Ω.m
Thermal conductivity	200 W/m.K
Thermal expansion	23.5×10^{-6} /K
Poisson's Ratio	0.33

Table 3:
Process Parameters and Their Levels

Machining parameter	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
			-1	0	1
Current	I_p	A	1	4	7
Pulse on time	T_{on}	µs	10	50	100
Powder concentration	P	g/l	0	4	8

V. RESULTS AND DISCUSSIONS

Nine experimental runs have been conducted and values of SR along with design matrix are given in Table 4. The analysis of variances for the factors is shown in Table 5 which is clearly indicates that the peak current and Powder concentration are the most influencing factors for SR. The delta values of Peak current, pulse on and powder concentration are 7.630, 2.057, 3.255 respectively, depicted in Table 6. The case of SR it is "smaller is better", so from this table it is clearly definite that Ip is the most important factor with powder concentration second then pulse on time third.

Table 4:
Experimental design matrix and collected data

S.no	Current (A)	Pulse on (µs)	Powder concentration (g/l)	SR(µm)		
				Si	Al	Gr
1	1	10	0	1.32	1.35	1.35
2	1	50	4	0.99	1.25	1.35
3	1	100	8	2.13	2.52	2.66
4	4	10	8	2.62	2.90	3.18
5	4	50	0	2.98	3.01	3.05
6	4	100	4	2.08	2.20	2.44
7	7	10	4	2.87	2.96	3.14
8	7	50	8	3.26	3.54	3.76
9	7	100	0	4.15	4.13	4.13

Table 5:
Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	2	90.670	90.670	5.335	13.50	0.069
Pulse on	2	6.839	6.839	3.420	1.02	0.495
Powder concentration	2	19.350	19.350	9.675	2.88	0.258
Residual Error	2	6.714	6.714	3.357		
Total	8	123.573				

Table 6:
Response Table for S/N Ratios Smaller is better (SR)

Level	Current	Pulse on	Powder concentration
1	-2.964	-6.346	-8.086
2	-8.071	-6.880	-5.144
3	-10.594	-8.403	-8.399
Delta	7.630	2.057	3.255
Rank	1	3	2

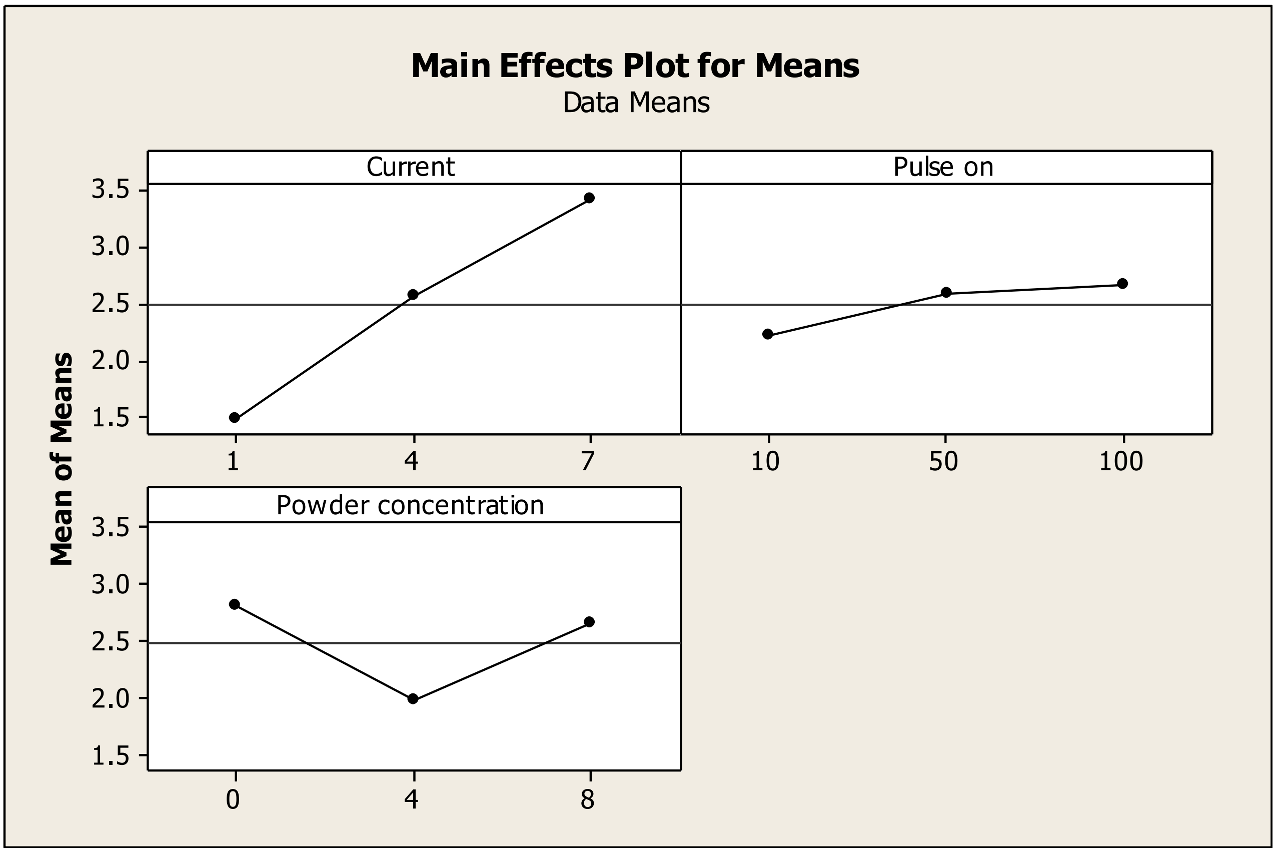


Fig. 2: Main effect plots for means SR

The influence of various machining parameter like of peak current, powder concentration and pulse on has significant effect on SR with Si powder, as shown in main effect plot for means of SR in Figure 2. The above figure shows SR increases with increase in peak current. The pulse on has least significant effect on SR. SR slightly increases first then there is stability in SR afterwards when pulse on is increased further. SR decreases with increase in powder concentration upto some limit.

VI. Conclusions

1) Current and powder concentration are significant factors affecting SR.
2) The SR is increased by increase in peak current.
3) SR decreases with the addition of silicon powder in the dielectric upto some level of concentration.
4) The optimum levels of various process parameters obtained in this work are:

Peak current = 1 A
Powder concentration = 4 g/l
Pulse-on time = 10 μs

REFERENCES

[1] K. Furutani, A. Saneto, H. Takezawa, N. Mohri, H. Miyake," Accretion of titanium carbide by electrical discharge machining with powder suspended in working fluid", Precis. Eng. 25 138–144,2001
[2] W.S Zhao.,"The Application of research on Powder Mixed EDM in rough machining", Journal of Materials Processing Technology 129 30-33, 2002
[3] Kobayashi, K.; Magara, T.; Ozaki, Y.; and Yatomi, T. (1992). "The present and future Developments of electrical discharge machining." Proc. of 2nd Int'l Conf. on Die and Mould Technology, Singapore, pp35-47.
[4] Narumiya, H.; Mohri, N.; Saito, N.; Otake, H.; Tsnekawa, Y.; Takawashi, T.; and Kobayashi, K. (1989). "EDM by powder suspended working fluid." Proc. of 9th ISEM, pp5-8.
[5] Mohri, N.; Saito, N.; and Higash, M. (1991). "A new process of finish machining on free surface by EDM methods." Annals of the CIRP (v40, n1), pp207-210.
[6] Pecas, P. and Henriques, E.A. (2003). "Influence of silicon powder mixed dielectric on conventional electrical discharge machining." Int'l Journal of Machine Tools and Manufacture (v43), pp1465-1471
[7] Wong, Y.S.; Lim, L.C.; and Tee, R.I. (1998). "Near mirror finish phenomenon in EDM using powder mixed dielectric." Journal of Materials Processing Technology (v79), pp30-40.
[8] W.S Zhao.,"The Application of research on Powder Mixed EDM in rough machining", Journal of Materials Processing Technology 12930-33, 2002
[9] Ming, Q.Y. and He, L.Y. (1995). "Powder-suspension dielectric fluid for EDM." Journal of Materials Processing Technology (v52), p44-54.
[10] Uno, Y. and Okada, A. (1997). "Surface generation mechanism in electrical discharge machining with silicon powder mixed fluid." Int'l Journal of Electro Machining (v2), pp13-18.
[11] K. M. Patel, Pulak M. Pandey, and P. Venkateswara Rao.," Understanding the Role of Weight Percentage and Size of Silicon Carbide Particulate Reinforcement on Electro-Discharge Machining of Aluminium-Based Composites", Materials and Manufacturing Processes, 23: 665–673, 2008