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Powder-Mixed EDM Machining of Aluminium-Silicon Carbide Composites

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Abstract

In the present work, the effects on the Characteristic Material Removal Rate (MRR) of aluminium based Metal Matrix Composites (MMC) are observed while varying peak current and aluminium powder concentration in kerosene dielectric fluid. Aluminium MMCs prepared by reinforcing Al with different concentrations of SiC (6%, 9% & 12%) using stir casting process are machined in EDM machine using a Copper Tool of Ø6mm while varying the considered process parameters which are the peak current (2A, 4A & 6A) and the concentration of Al powder in dielectric fluid (0g/l, 1g/l & 2g/l). Experiments were conducted at a constant pulse on-time of 65μs at a duty cycle of 70% and a constant voltage of 40V. It is observed from results that the MRR increases at low peak current of 2A during PMEDM machining of Al/SiC composites.

Keywords: Al Powder, Al6061/SiC Composites, MRR, PME

1. Introduction

Electric Discharge Machining (EDM), also known as spark erosion or spark machining is among the most popular unconventional machining processes used for the machining of conductive material irrespective of their strength or toughness. EDM can be used for the machining of modern alloys and composites which are being made to posses high toughness, high strength and high stiffness properties due to the increasing demands of the aerospace, tooling and structural industries. These desirable properties of the modern materials also make them hard to be machined by using conventional machining processes and EDM provides an easy way to machine these modern alloys and composites irrespective of their strength and toughness values. Though, EDM can be used to machine complex shapes easily it has certain limitations such as low machining rate and poor surface finish. Many methods have been developed to improve the surface finish and the machining efficiency of EDM which include: (a) Electrode orbiting - providing planetary motion to either work piece or tool, (b) providing Tool Rotation, (c) Providing Ultrasonic vibration to Tool, (d) mixing conductive particles in dielectric fluid. Among these, introducing conductive particles in the dielectric fluid is a recent development[1].

This method of introducing conductive particles in the dielectric fluid is known as powder mixed EDM (PMEDM). The conductive powder particles in the dielectric fluid increases the gap between the Tool and the work piece while providing a bridging effect between the electrodes for an even distribution of spark energy making the process more stable[2].

Literature survey shows that many researchers have come to a conclusion that the powder mixed EDM has a prominent future but for an implementation of the process in industrial applications further research is needed to completely understand the complex mechanism of powder mixed EDM (PMEDM). It is also observed from literature survey that much work is not carried out in the machining of composites using PMEDM process. So, in this paper the effects of process parameters on the MRR of Al6061 reinforced with different concentrations of SiC are studied.

2. Experimental Setup

Die sinking EDM machine is used to perform the machining operations. The machine has a tank dimension of "700 mm X 500 mm X 350 mm", so; as a result it needs large amount of aluminium powder to contaminate the dielectric fluid in the tank to get desired concentration

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for the experimentation and it also leads to usage of more dielectric fluid for the experimentation, moreover the usage of filtering techniques would also increase difficulties in conducting experimentation. So, to overcome these difficulties a new tank, having volume of 7 liters with incorporated work holding device, has been chosen for conducting experimentation. For proper blending of aluminium powder with dielectric fluid and circulating the same in the spark gap, a special and portable electric pump is fixed with the EDM machine. This setup used for performing experimentation is shown in Figure 1. Figure 2 shows Al/SiC (9%) work piece clamped to the work holder.

Aluminium reinforced with three different percentages of SiC (6%, 9% and 12%) are used as work piece materials and these work pieces are fabricated by 'stir casting method'. The tool electrode used for machining is copper rod having 6 mm diameter. Aluminium powder with various concentrations (0 g/l, 1g/l and 2g/l) are blended with dielectric fluid for the experimentation.

A random experiment is conducted to ascertain few fixed parameters and to find out the range of the process parameters to be used in the experimentations, these parameters are shown in the Tables 1 and 2.

After fixing the process parameters, experiments are designed on the basis of "FACE CENTERED CENTRAL COMPOSITE DESIGN". This FCCCD comprises three level factorial points and star points at the center of each face.

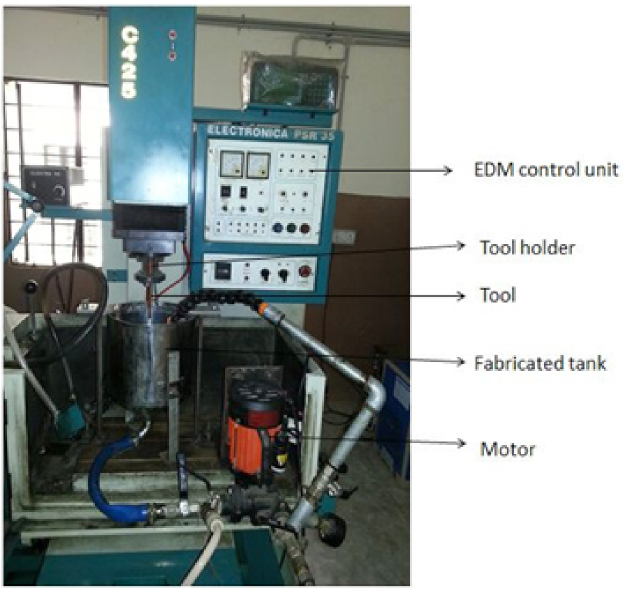

Figure 1. Photograph of experimental setup.

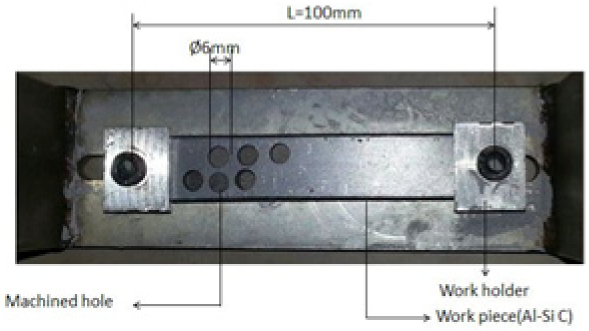

Figure 2. Photograph of Al-SiC (9%) work piece.

Table 1. Fixed parameters

S.No.	Fixed parameter	
1	Workpiece	Al-SiC
2	Tool	Copper (Cu)
3	Polarity	Normal
4	Machining time	10 mins.
5	Dielectric fluid	Kerosene mixed with Al powder
6	Aluminium powder particle size	27 microns
7	Duty factor	75%
8	Pulse on-time	65 µs

Table 2. Process parameters used to conduct experiments

S.No.	Process parameter	Values
1	Concentrations of Al powder	0 gm/l, 1 gm/l & 2gm/l
2	Concentration of SiC in Al	6%, 9% & 12%
3	Peak current	2 A, 4 A & 6 A.

3. Regression Analysis

The regression analysis is performed to develop the MRR equation which shows the clear dependency of material removal rate on the parameters I, C, C_p which are the indicated terms, the terms I×I, C×C, $C_p \times C_p$ which are the higher order terms and the terms I×C, I×C_p, C×C_p which are the interacting terms. Depending on the significance of these terms from regression analysis and ANOVA the main equation of MRR is derived which can be used to find the MRR for different values of the terms in the equation. The Table 4 gives the results for regression analysis and ANOVA.

Table 3 gives the experimental plan developed based on the face centered central cubic design along with the MRR observed for the experimentations conducted for corresponding combinations of the parameters. The output responses (i.e. MRR observed) were entered into the MINITAB software to perform regression analysis.

3.1 Material Removal Rate

The value for the material removal rate can be obtained in uncoded units can be measured by using the following equation which considers all parameters.

$$MRR\left(\frac{mg}{\min}\right) = 19.7250 + 12.6802 \times I - 12.3024 \times C + 31.5312 \times Cp + 0.0984I \times I + 0.6532C \times C - 6.5164Cp \times Cp + 0.4092I \times C - 5.7000I \times Cp - 0.5192C \times Cp$$

ANOVA analysis indicates that C_p and I×C_p are the most significant terms since their p-values are less than the 0.05. By neglecting the insignificant terms from above equation the approximate value for the MRR can be calculated by

$$MRR\left(\frac{mg}{\min}\right) = 19.7250 + 31.5312Cp - 5.7000I \times Cp$$

Table 3. Experimental plan along with MRR responses

S.No.	I (A)	C (%)	C_p (gm/l)	MRR (mg/min)
1	2	12	2	6.86
2	4	9	1	29.42
3	2	12	0	0.21
4	4	9	1	29.42
5	6	6	2	29.87
6	4	12	1	24.92
7	2	9	1	4.96
8	6	12	2	29.30
9	4	9	0	18.01
10	2	6	2	0.91
11	4	9	1	29.42
12	4	9	1	29.42
13	6	12	0	84.59
14	2	6	0	4.37
15	4	9	2	13.09
16	4	9	1	29.42
17	6	9	1	39.96
18	4	6	1	30.97
19	6	6	0	62.59
20	4	9	1	29.42

Table 4. ANOVA for MRR

Source	DF	SEQ SS	ADJ SS	ADJ MS	F	P
Regression	9	7340.74	7340.74	815.64	14.91	0.000
Residual Error	10	547.15	547.15	54.71		
Total	19	7887.89				

4. Results and Discussions

4.1 Effects of Process Parameters on MRR

The effects of the considered process parameters (i.e. peak current (I), concentration of aluminium powder in dielectric fluid (C_p) & concentrations of SiC in Al (C)) on the material removal rate (MRR) of the work-piece are explained in this section. Graphs have been plotted to study the effects of the process parameters on MRR by fixing one process parameter as constant and varying the other two process parameters.

4.2 Effects of Peak Current on MRR

Figure 3 gives the plot which shows the variation of MRR with respect to the variations in the process parameters of peak current (I) and concentration of SiC in Al (C) while the concentration of aluminium powder in dielectric fluid

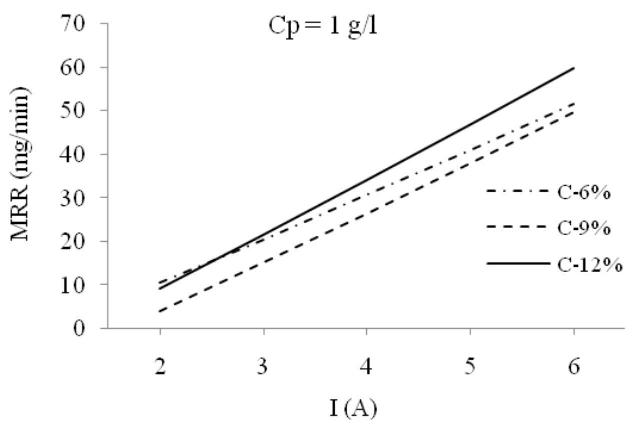

Figure 3. Plot for I and C vs. MRR.

(C_p) is kept constant at 1gm/l. It can be observed from the plot that the maximum MRR of 59.8228 mg/min is obtained at the highest peak current of 6A. The MRR is also observed to be increasing proportional to peak current i.e the MRR increase with increasing peak current. This may be due to the fact that the energy per pulse increases with an increase in the peak current and MRR is directly proportional to energy per pulse. A similar trend was observed by Kathiresan & Sornakumar[3], who had also concluded that with an increase in peak current, MRR increases.

It can be observed from the plot that at C_p = 1gm/l, the MRR decreases for any value of peak current with increase of concentration SiC from 6% to 9% but as concentration of SiC increases from 9% to 12%, there is an increase in MRR which shows that with the machining of Al-SiC with 9% concentration of SiC is the most difficult to machine.

4.3 Effects of Concentration of Silicon Carbide in Aluminium Composite on MRR

Figure 4 gives the plot in which for a fixed peak current of 4A, the effects of variations in the process parameters of concentration of silicon carbide in aluminium matrix (C) and concentration of aluminium powder in dielectric fluid (C_p) on MRR are observed. It can be seen from the plot that with an increase in the concentration of SiC from 6% to 9% there is decrease in MRR but as SiC concentration further increases from 9% to 12%, there is increase in MRR observed. From this, it can be inferred that machining of Al-SiC composite with 9% concentration of SiC is the most difficult to machine by this process in comparison to other concentrations of silicon carbide in aluminium matrix.

It can also be observed that for any concentration of SiC in Al, there is a decrease in MRR with an increase in the concentration of aluminium powder in the dielectric fluid. This may be because of the frequent short circuiting due to the bridging of the inter electrode gap and which results in reduced machining efficiency[4].

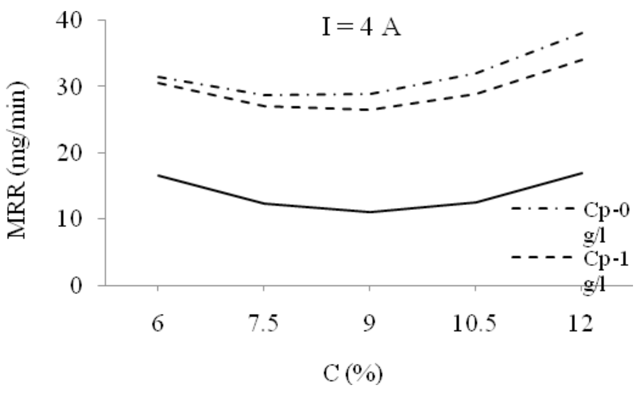

Figure 4. Plot for C and C_p vs. MRR.

4.4 Effects of Concentration of Aluminium Powder in Dielectric Fluid on MRR

Figure 5 gives the plot which gives the effects on MRR with variations in the process parameters of changing peak current (I) and changing concentrations of aluminium powder in dielectric fluid (C_p) while the concentration of silicon carbide in aluminium matrix is constant at C = 9%. It can be observed from the plot that with the increase in the concentration of the aluminium powder the MRR generally decreases which is due to the frequent short circuiting between the powder particles resulting in lower energy transfer to work piece for effective material removal. This trend is observed for constant peak currents of 4A and 6A. However, at peak current of 2A, there is an increase in MRR for increasing concentration of powder from 0 gm/l to 1 gm/l. This may be due to the fact that at 2A peak current this is due to the fact that, the amount of debris between the electrodes is less which is promoting stable machining conditions. But, as the peak current increases an increase in debris between the inter-electrode gap causes higher rate of short circuiting at higher peak currents leading to reduction in MRR. It was also observed by Erden and Bilgin et al[4] that at excessive powder concentration machining becomes unstable.

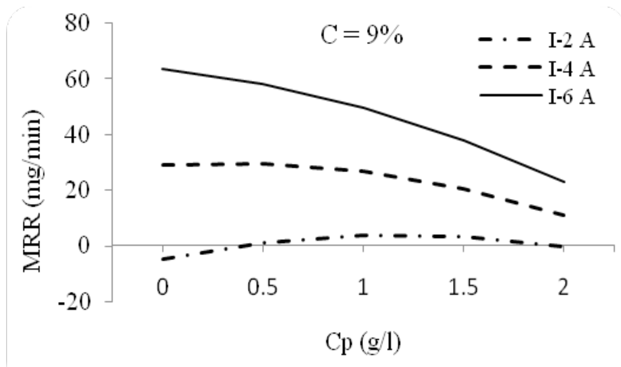

Figure 5. Plot for C_p and I vs. MRR.

5. Conclusion

By considering the results obtained from the experimentation, the following conclusions can be inferred:

1. The Material Removal Rate (MRR) increases with increase in the peak current irrespective concentration of silicon carbide in aluminium metal matrix composite.
2. The MRR for 9% concentration of silicon carbide in aluminium is the lowest irrespective of the peak current and powder concentration in dielectric fluid.
3. At lower peak current (2A), the MRR increases with the increase in the aluminium powder concentration in the dielectric fluid up to a certain limit.

6. References

1. Kansal HK, Singh S, Kumar P. Numerical simulation of powder mixed electric discharge machining (PMEDM) using finite element method. Math Comput Modell. 2008; 47(11–12):1217–37.
2. Kansal HK, Singh S, Kumar P. Effect of silicon powder mixed EDM on machining rate of AISI D2 die steel. J Manuf Processes. 2007; 9(1):13–22.
3. Kathiresan M, Sornakumar T. EDM Studies on aluminum alloy-silicon carbide composites developed by vortex technique and pressure die casting. Journal of Minerals and Materials Characterization and Engineering. 2010; 9(1):79–88.
4. Erden A, Bilgin S, editor. Role of impurities in electric discharge machining. 21st International Machine Tool Design and Research Conference; 1980; London. Macmillan.