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Electrical Discharge Machining Characteristics of Hybrid Mg/Sicp/Flyash Composites

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ABSTRACT
The objectives of this research is to prepare the hybrid Mg/SiCp/Flyash metal matrix composite through powder metallurgy technique and investigate the effects of process parameters like current, pulse on time and pulse off time in Electro Discharge Machining characteristics on material removal rate and tool wear rate. The composition is selected on weight percentage basis SiC with 6 % and 6% fly ash with constant 88% Mg as matrix material. With proper uniform distribution particulate dispenses wisely which is evident from SEM analysis. The electrical discharge machining was done though the ELEKTRA PLUS spark erosion machine. Brass tool with 10 mm diameter is used to machine the specimens. Current (I), pulse on time (Ton) and pulse off time (Toff) parameters were varied in this electrical discharge machining process. Experiments were conducted under different conditions of pulse on time (Ton), pulse off time (Toff), current (I). The output responses measured were material removal rate (MRR) and Tool wear rate (TWR). Mathematical models are proposed for the above responses using response surface methodology (RSM). The analysis of variance (ANOVA) was carried out to study the effect of process parameters on process performance.
Keywords - *EDM, Mg/SiCp/Flyash composites, MRR, TWR.*

1. INTRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. Metal matrix composites (MMC) are gaining increasing attention for applications in aerospace, defence, and automobile industries. Magnesium alloys is promising materials because of their low density, high specific strength, high specific stiffness, good dimensional stability and high damping capacity. [1-5]. Nowadays the silicon carbide developed to high quality ceramic with high mechanical properties. Silicon carbide also used for electrical conductor like flame igniters, electronic components and resistance heating. Structural applications and wear applications also recently developed on silicon carbide particulates [6]. Flyash is one of the residues generated in the combustion of coal. It is an industrial by-product recovered from the flue gas of coal burning electric power plants. In solid state process the composites are obtained with fine microstructure and uniform distribution. In generally the solid state process methods are diffusion bonding and powder metallurgy [7]. Powder Metallurgy (PM) is production of metals in powder form and the manufacture which is known as sintering [8]. The machining of MMC is difficult due to the highly abrasive nature of ceramic reinforcements when traditional machining was used. Electrical Discharge Machining is a thermoelectric process in which heat energy of a spark is used to remove material from the work piece using a tool (electrode), where both tool and work piece are electrically conductive [9,10]. Statistical models have been developed using response surface methodology based on experimental results considering the machining parameters, viz., current (I, amp), pulse-on time (Ton, μs) and pulse-off time (Toff, μs) as independent variables. Finally, an attempt has been made to obtain optimum machining conditions with respect to each of the machining parameters considered in the present study with the help of response optimization technique.

2. EXPERIMENTAL PROCEDURE

Magnesium (Mg) powders were used as matrix material. Particles size of 60μm. Reinforcement was used as Silicon carbide particles and Flyash. Silicon carbide particles size 60μm. The addition of SiC particle improves the wear resistance and brittleness. The weight fraction of Sic particles was 6 %. Flyash average particles size was 40μm. The weight fraction of flyash was 6%. The composites were prepared using powder metallurgy route. The Mg powders and the SiC & flyash particulates were mixed by using a rotating ball milling machine under a rotating speed of 300 rpm for 3 hrs. Fabrications of the composites at appropriate sintering temperature of Mg were determined. Ball milled Mg/SiCp/Flyash powder was poured into a 30 mm diameter die and then pre-pressed with a pressure of 15MPa. After pressing, the die was put into the (furnace chamber) and then sintered at temperature of 550°C with pressure of 30MPa and holding time of 15 min

2.1 Equipment Used

The machine used for machining is an 'Electra plus' EDM machine having the stepped drive servo system and filtration flushing capability. Copper tool having 99.9% copper in composition was used as tool electrode. A cylindirical tool with 10 mm diameter was used to machine the specimens. Kerosene was used as dielectric fluid because of its high flash point, good dielectric strength, transparent characteristics and low viscosity and specific gravity. It is capable of generating maximum pulse current of 25 ampere, pulse on time of 2000 μs and pulse off time of 2000 μs. Metal removal rate (MRR) is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time,

MRR=[(Wwb-Wwa)/t] (g/min) (1)

Where Wwb and Wwa are the weights of the work piece before and after machining, and t is the machining time. Tool wear rate is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time,

TWR=[(Wtb-Wta)/t] (g/min) (2)

Where Wtb and Wta are the weights of the tool before and after machining and t is the machining time.

MRR and TWR are directly calculated from the experimental data. The weight of the specimen is taken before and after the machining process using a digital weighing machine with an accuracy of 0.0001g. Before weighing, the specimen is cleaned and dried to relieve it from debris and dirt. The difference of weight before and after machining gives the weight loss of the work piece during machining process. This weight is divided with machining time to get the metal removal rate and tool wear rate in g/min.

2.2 Response Surface Methodology

Response surface methodology is an experimental technique used for predicting and modeling complicated relation between independent factors and one or more responses (Box et al., 1951). In this study, response surface methodology was applied to optimize the Material Removal Rate and Tool Wear Rate by EDM. Experiments were performed using centered composite design (CCD). The second-order polynomial equation extended with additional cubic effects was employed as an objective function. Thus, in this study the second order polynomial equation were used. Accuracy of model fitting was evaluated by means of ANOVA. All calculations were performed in Design Expert-8.0.

2.3 Design of Experiments and Data Collection

In the present study, a Central Composite design (CCD) was employed for determining the optimum values of parameters. Thus, the total number of design points in a CCD is n = 2k + 2k + n0. 2 x 3(factorial point) + 2 ×3(axial point) + 6 (central point) = 20. In Table 1 and 2 series of experiments according to experimental plan based on CCD design.

Table 1 Machining Parameters and their Corresponding Levels

Machining Parameters	Symbols	Units	Levels		
			-1	0	1
Current	I	A	5	7.5	10
Pulse On Time	t_{on}	µs	200	600	1000
Pulse Off Time	t_{off}	µs	50	125	200

Table. 2 Observed MRR & TWR

Std Order	Run order	I Actual value (A)	Ton Actual Value (µs)	Toff Actual Value (µs)	MRR (g/min)	TWR (g/min)
1	8	10	1000	200	0.2759	0.0006
2	17	7.5	600	125	0.2012	0.0003
3	2	10	200	50	0.228	0.0006
4	14	7.5	600	200	0.2139	0.0003
5	16	7.5	600	125	0.2012	0.0003
6	19	7.5	600	125	0.2012	0.0003
7	11	7.5	200	125	0.1802	0.0005
8	7	5	1000	200	0.1551	0.0005
9	10	10	600	125	0.2476	0.0005
10	13	7.5	600	50	0.2003	0.0004
11	9	5	600	125	0.1236	0.0003
12	5	5	200	200	0.1161	0.0003
13	3	5	1000	50	0.1466	0.0003
14	4	10	1000	50	0.2599	0.0005
15	12	7.5	1000	125	0.2253	0.0004
16	18	7.5	600	125	0.2012	0.0003
17	20	7.5	600	125	0.2012	0.0003
18	1	5	200	50	0.1096	0.0004
19	15	7.5	600	125	0.2012	0.0003
20	6	10	200	200	0.235	0.0005

3. RESULT AND DISCUSSION

3.1 Microstructure Characteristics of Mg/SiCp/ Flyash Composites

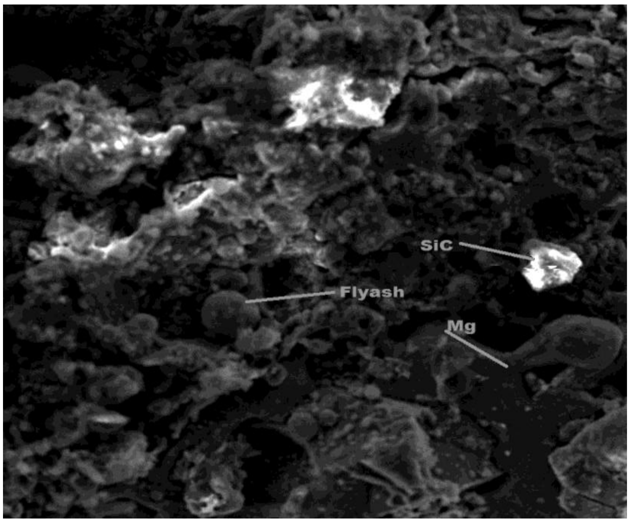

Fig. 1 SEM Microstructures of Mg/SiCp/Flyash composites

Fig 1 shows that the SEM micrographs reveal that the dispersion of SiC and Fly ash particles in the matrix is homogeneous. The distribution of the SiCp and flyash particles appears to be uniform throughout the magnesium matrix.

3.2 Effect of Process Parameters on Material Removal Rate

Fig 2 shows that the interaction effect between the current and pulse on time with material removal rate. Material removal rate is increase with increase of current for all values of pulse on time, similarly the material removal rate is increase with increase of pulse on time for all values of current. The material removal rate is observed as low of 0.1161 g/min with the combination of current 5A and pulse on time 200 µs. The maximum material removal rate of 0.2759 g/min is measured at current 10A and pulse on time off 1000 µs. The localized temperature is increased due to high current and pulse on time. An increase in the current improves the rate of melting and evaporation and the impulsive force of expanded dielectric fluid. The maximum thermal stocking is developed on the composite. Hence, it leads to maximum MRR.

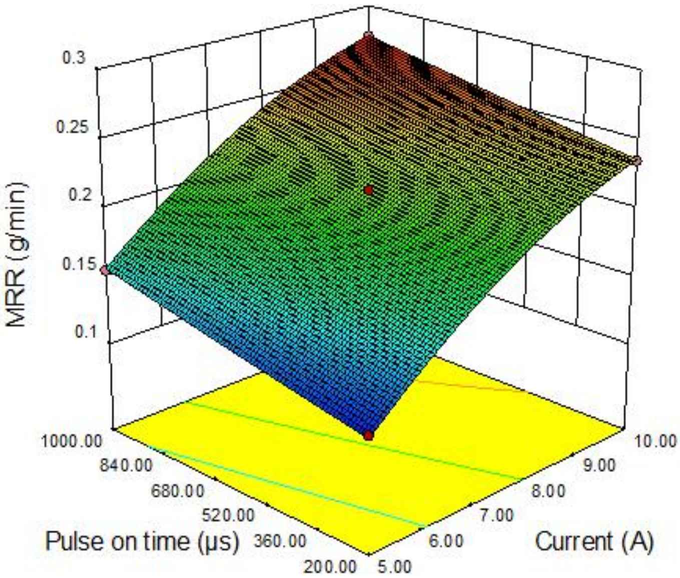

Fig. 2 Interaction Plot between Current and Pulse on Time for MRR

It is observed from Fig 3 that interaction effect between the current and pulse off time with material removal rate. Parameter current is increase the material removal rate also increase significantly with all values of pulse off time, similarly pulse off time increases the material removal rate also increases with slightly at all values of current. Material removal rate is observed as low of 0.1466 g/min at the current of 5A and pulse off time of 50µs. The maximum material removal rate is observed as 0.2579 g/min with current of 10A and pulse off time of 200 μs. Increase duration of pulse off time increases the number of discharges within a given period. Thus, less discharge energy is impinged on the work piece in a given time that increases the rate of metal erosion, thereby increase the material removal rate slightly.

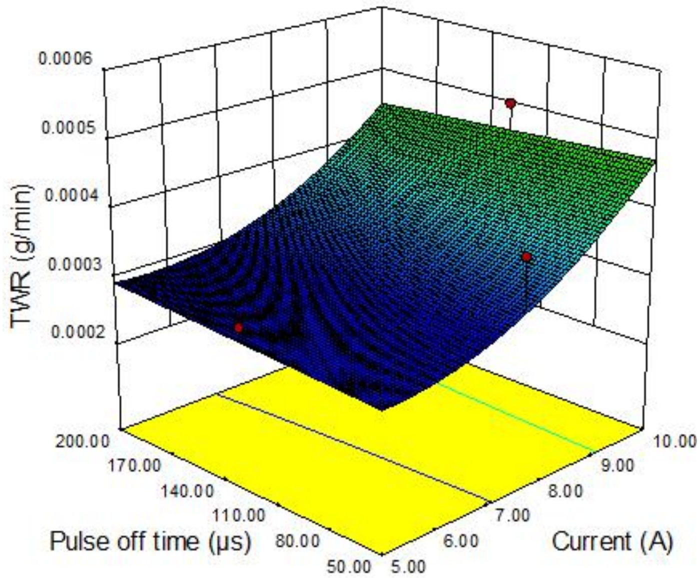

Fig. 3 Interaction Plot between Current and Pulse off Time for MRR

3.3 Effect of Process Parameters on Tool Wear Rate

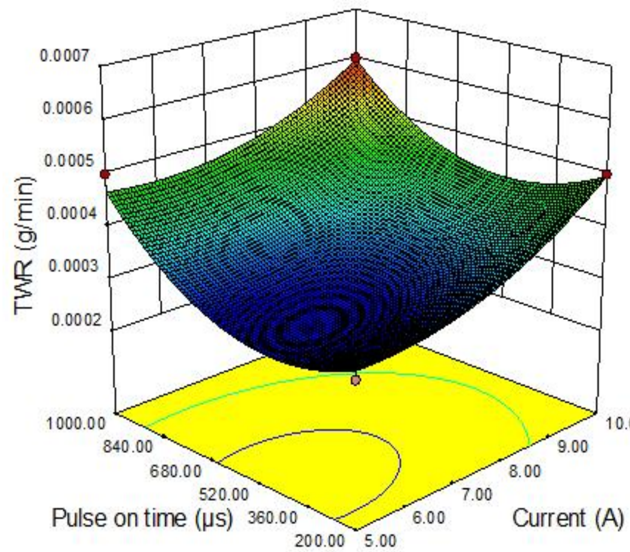

Fig. 4 shows the effect of pulse on time and current on TWR criteria. It shows that the tool wear rate values increase as the current values increase for all value of pulse on time. It also shows that the tool wear rate decreases with increase of current, further increase of pulse on time the tool wear rate started to increase with all values of current. The minimum tool wear rate is observed as 0.0003 g/min with current of 5A and pulse off time of 200μS. With the combination of current 10A, and pulse on time 1000μs the tool wear rate is observed as 0.0006 g/min.

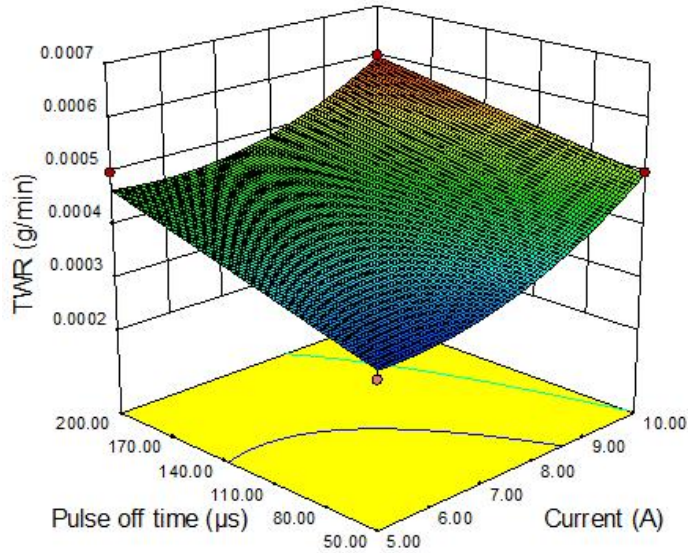

Fig. 5 shows the interaction effect of current and pulse off time on the tool wear rate for a preset pulse off time. The figure demonstrates that for each chosen current, the TWR increases with increase in the pulse off time. The tool wear rate initially decrease with increase of pulse on time, further increase pulse on time the tool wear rate also increases with all values of current. The minimum TWR ids observed of 0.0003 g/min at the current of 5A and pulse off time of 50μs. The maximum of 0.0006 g/min material removal rate is observed at current of 10A and pulse on time of 1000μs.

4. CONCULSIONS

This experiment was carried to investigate the influence of the current, pulse on time and pulse off time for the MRR and TWR characteristics. It was also attempted to formulate mathematical model for the responses such as MRR, and TWR and finally to derive the optimal settings of the parameters for the EDM process.

From the SEM micrograph of hybrid Mg/SiCp/ Flyash, it is observed that the Flyash and SiC particles embedded in the matrix is visible showing uniform distribution of reinforcements. Good interfacial bonding between the SiC and flyash particles and matrix materials.

For hybrid Mg/SiCp/Flyash metal matrix composite the MRR is measured the maximum of 0.2296 g/min and the minimum of TWR is measured of 0.0003 g/min with the optimized condition of current 8.5 A, pulse on time 700µs and pulse off time 200 µs

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