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Effect of Electrical Discharge Machining Parameters on Machining Characteristics of Metal Matrix Composites

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ABSTRACT

Parametric analysis of die-sinking Electric Discharge Machining (EDM) of 10 wt.% alumina particulate reinforced Al6061 matrix composite has been performed using one-parameter at-time- approach. Individual effect of change of voltage, pulse-on-time, peak current and duty factor on output response i.e., material removal rate (MRR) and surface roughness (Ra) has been analysed with detail discussion on the physics of the EDM process. Experiments were performed by varying one input parameter while keeping other parameters at constant value during die sinking EDM of MMC using copper electrode. The analysis revealed that increase of pulse on time increases the Ra but decreases the MRR. MRR increases with the increase of duty factor, but it bears nonlinear relationship with Ra. The increase of voltage initially decreases the Ra but at higher values Ra values increases exponentially. The increase of peak current always increases the MRR and Ra.

Keywords - metal matrix composite, duty factor, pulse on time, EDM, voltage

1. INTRODUCTION

When more than two materials are combined to form a material with superior properties compare to the primary components is called composite [1]. Aluminum metal matrix composites (MMC) makes it a suitable material for aerospace application due to its good sliding wear properties [2]. MMCs are being used in many lightweight engineering applications due to its greater specific strength and excellent wear properties [3]. Kandpal et al. prepare aluminum MMC reinforced with aluminum oxide in 5,10, 15 and 20 percent by stir casting and investigated its behavior by scanning electron microscope [2]. Aluminum MMC can be produced by stir casting with minimum cost [4,5]. Kumar et al. [5] found that for preparation of particulate reinforced MMC, stir casting is an economical process and authors prepared aluminum based MMCs using SiC, Graphite and aluminum oxide as reinforcement in different proportions. Sajjadi et al. fabricated nano and micro composite using two different methods i.e., stir-casting and compo-casting [6].

Now a days many MMCs has been developed which is hard and tough, therefore machining of these materials is exceedingly difficult by conventional machining. So, for machining these types of materials which is brittle and hard in nature, electrical discharge machining (EDM) is used because EDM can machine extremely hard materials possessing electrical conductivity [7]. In EDM process material removal take place due to electric spark for a very small duration and higher current density among the workpiece material and tool. In EDM process for MRR, pulse on time and pulse off time play an important role, and during the pulse on time material get melts and during the pulse off time material removal occurs due to removal of sludge by EDM. Lau et al. conducted EDM of the composite materials [8]. Optimization of EDM for machining of composites materials were performed by Chin et al. [9].

An investigate done by Singh et al on the effect of EDM process parameters such as impulse frequency, voltage, types of flushing dielectric pressure, dielectric pressure and electrode material during machining of mild steed. It was found that graphite electrode yields good MRR but poor surface finish compared to brass and copper electrode. They also proposed that low voltage produces high MRR with poor surface finish and high voltage yields low MRR with good surface finish and geometrical accuracy [10]. Puertas et al. optimized the EDM for surface quality and precision machining [11]. Wang et al. [12] optimized the blind-hole drill in Al203/6061Al composites by using taguchi optimization technique [12]. Paswan et al. studied the function of steam as dielectric medium in EDM for machining of aluminium MMC. The effect of input parameter on recast layer, MRR and surface roughness were explored [13]. The sustainability of EDM were assessed and the environmental impact of hydrocarbon-based dielectric to green dielectric such as water, dry EDM and near-dry EDM has been analysed [14,15].

In this paper an Aluminum based MMC has been prepared by mixing alumina (Al2O3) 10 % wt. in aluminum matrix by stir casting. After that analyze the effect of input process parameters i.e., pulse on time, peak current, voltage gap and duty factor on MRR and SR has been investigated using one parameter at a time approach on EDM by cutting a depth of 0.75 mm on the fabricated aluminum MMC.

1.1 Fabrication of Aluminium metal matrix composites

1.1.1 Matrix and reinforcement selection: In this work to aluminum alloy 6061 was chosen as the matrix phase for preparation of composites material which is mostly use in various structural and defense application due to its high strength, low weight and good wear properties. Aluminium oxide also known as alumina with chemical composition Al_2O_3 were taken as reinforcement which melting temperature is 2072 ^{0}C. It is the most widely used reinforcement with aluminium compared to other reinforcement such as silicon carbide or boron carbide etc. To prepare aluminium metal matrix 10 wt % alumina was mixed with the aluminium matrix.

1.1.2 Fabrication of Composites: To fabricate the composite, stir casting method was used. In stir casting method there was difficulty in uniform mixing and distribution of reinforcement in matrix, wetting ability between matrix and reinforcement, porosity and chemical reaction between reinforcement and matrix at high temperature are the main challenges.

To fabricate Aluminium MMC by stir casting firstly Al6061 were melted in the graphite crucible by heating in electric furnace up to 800 0C. After that alumina powder were mix in this molten metal by four bladed stirrer of steel for 10 minutes. Before mixing the alumina, it is preheated up to 550 0C so that moisture content can be release. After mixing alumina in the molten metal, it further heated up to 900 0C before pouring in the mould.

2. EXPERIMENTAL DETAILS

During this study experiment are perform on ELEKTRA Pulse S- 50 ZNC EDM which is shown in figure number 1 and in figure number 2 monitor of EDM are shown which display the experimental condition. To perform the experiment four process parameters i.e. duty factor, peak current, voltage gap and pulse on time were taken into consideration. The ratio of pulse on time to pulse off time is defined as duty factor.

To find the optimum level of EDM a pilot experiment was perform. From pilot experiment minimum and maximum level of input parameters were obtained which taken in to consideration for the experiment.

Fig 1. CNC die sinking EDM

Fig 2. Monitor of die sinking EDM

3. METHODOLOGY

In this study experiments were conducted using the 4 factors at 3 levels to analyse its effect on MRR and surface roughness. One parameter at a time approach were use, where only one factor was changed keeping other three factors constant has been applied for parametric analysis. Effect of pulse on time, peak current, voltage and duty factor on MRR and surface roughness were investigated. Table 1 show the value of different factors at three levels. Table 2 indicate the experimental data which has been obtained during actual machining EDM.

Table 1. Factors and their level

Sr. No	Input Parameters	Levels			Units
		1	2	3	
1	Voltage (V)	40	50	60	V
2	Peak Current (I)	5	10	15	A
3	Pulse on time (T_{on})	100	200	300	µs
4	Duty Factor (t)	5	7	9	

In this experiment MRR were calculated by taking the difference of initial weight of workpiece to the final weight of workpiece in grams which was weighing by digital weighing equipment which accuracy was 0.01 gram with respect to time in minutes. Before measuring the final weight of workpiece, machined surface was cleaned by the cloth properly so that minor dust particle which is adhesive on the surface could remove properly.

Table 2. Experimental data

Exp No	Factors				Responses	
	V	I	T_{on}	t	MRR x 10^{-2} gm/min	SR (μm)
1	40	10	200	7	10.429	10.53
2	50	10	200	7	14.175	9.33
3	60	10	200	7	13.860	10.43
4	50	5	200	7	4.002	6.36
5	50	10	200	7	13.632	9.10
6	50	15	200	7	20.210	13.86
7	50	10	100	7	15.115	8.80
8	50	10	200	7	12.000	9.56
9	50	10	300	7	11.262	11.00
10	50	10	200	5	11.186	10.96
11	50	10	200	7	12.320	10.70
12	50	10	200	9	15.789	11.30

4. RESULTS AND DISCUSSIONS

4.1 Effect of Voltage

Form Fig 3 it is clear that when voltage increases from 40 V to 50 V, MRR increases. Furthermore, when voltage increase from 50 V to 60 V MRR first increases and after that it starts decreasing. Fig 4 indicates that when voltage increases from 40 V to 50 V surface roughness start decreasing till the lower 50 V and when further voltage increases from 50 V to 60 V surface roughness value start increasing. This happens because when voltage increases, the discharge time is longer so average discharge gap is higher. Therefore, discharge condition is more stable, and number of discharge cycle decrease with in the given period due to this when voltage increase from 40 V to 50 V MRR increase and surface roughness decrease but when further voltage increases MRR starts to decrease and surface roughness increases.

4.2 Effect of Peak current

Fig. 5 shows that due to increase in the peak current from 5 A to 10 A, MRR increase with higher rate and from 10 A to 15 A, MRR increase with decreasing rate. So, it is clear that when peak current increase then MRR increase in concave way. This is due to when peak current increases, discharge energy is also high therefore melting and evaporation of material increases causing higher MRR. Fig. 6 demonstrate that when peak current increase surface roughness increases with decreasing rate or convex profile. It might be due to increase in evaporation rate increase which produce high SR.

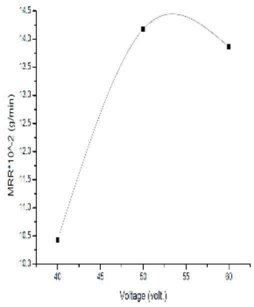

Fig 3. Effect on MRR of voltage

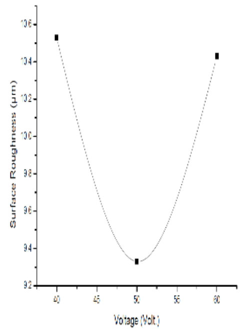

Fig 4. Effect on SR of voltage

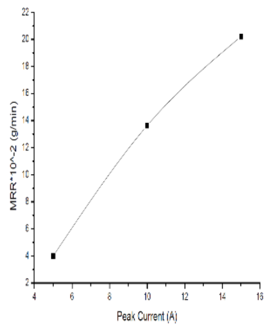

Fig 5. Effect on MRR of Peak current

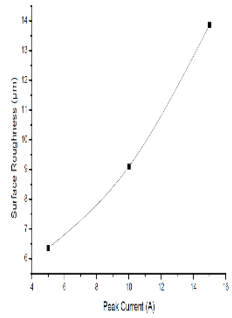

Fig 6. Effect on SR of Peak current

4.3 Effect of Pulse on time

From Fig 7 it can be observed that when duration of pulse on time increases, MRR start decreases, because in traditional EDM when pulse on time increase plasma channel expanded more hence results in lowering of energy density and impulsive force. When impulsive force reduces it does not remove the melted material thereby reducing the MRR. Fig. 8 elucidate that when value of pulse on time increases SR also increases.

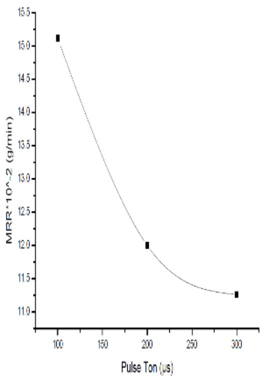

Fig 7. Effect on MRR of Pulse on time (Ton)

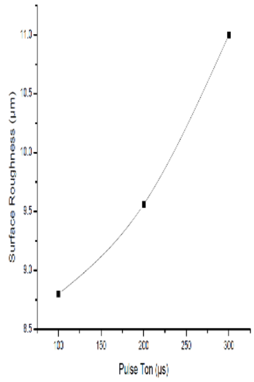

Fig 8. Effect on SR of Peak current

4.4 Effect of Duty Factor

Fig 9 shows that when duty factor increases from 5 to 9, MRR increases continuously due to increase in pulse on time compared to pulse off time. Secondly due to more duty factor high spark energy is released causing higher melting of workpiece material. Fig.10 indicates that when duty factor increases from 5 to 7, surface roughness begins to decrease after which it increases. When the duty factor increases from 7 to 9, surface roughness continuously increases.

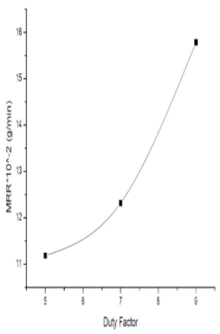

Fig 9. Effect on MRR of Duty Factor.

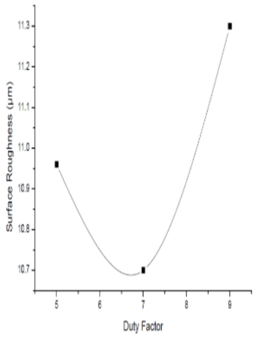

Fig 10. Effect on Surface Roughness of Duty Factor.

Fig 11. Machined Al/Al2O3 composites.

Fig. 11 show the machined aluminium metal matrix composites by the use of copper electrode tool with 0.750 mm hole depth.

5. CONCLUSIONS

Following conclusions can be drawn based on the parametric analysis of EDM using one parameter at a time approach.

a. Increase of voltage, increases MRR but at higher values of voltage MRR decreases, and surface roughness is minimum at 50 V and it increases or decrease when the voltage is other than 50V.

b. On increasing peak current, both surface roughness and MRR increases. But MRR increase in concave profile and SR increase in convex profile.

c. On increasing the pulse on time, it is observed that MRR decrease and surface roughness increase.

d. When duty factor increases, pulse on time increase in comparison to pulse off time then MRR increase in convex profile, and surface roughness firstly decrease rapidly when duty factor increases, further more increase in duty factor SR increase rapidly.

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