

Effect of Process Parameters on Material Removal Rate in μ -EDM of Magnesium Nano-Composite

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Abstract - Electrical discharge machining (EDM) is a manufacturing process in which electrical discharges are used to bring about a desired shape of a workpiece. In this research work, the material removal rate (MRR) is studied by optimizing the μ -EDM process parameters such as pulse on time, pulse off time, voltage gap and duration. The work materials used was Magnesium nanocomposites (reinforced with 1.98% and 2.50% Titanium Carbide). The experiment was designed as per L9 orthogonal array method. Taguchi analyses were carried out in finding the significant factors which causes changes in MRR. Pulse on time was found to have the most significant impact on MRR while pulse off time and voltage gap were found to have a relatively lesser impact on MRR.

Key Words: μ -EDM, Magnesium Nanocomposite, MRR, Taguchi, Titanium Carbide

1. INTRODUCTION

There has been an increase in demand for the application of lightweight materials in the aerospace, automobile and biomedical industries. Although magnesium is a soft metal, metal matrix composites based on magnesium are difficult to machine using conventional methods [1]. Inaccuracy in drilling micro sized holes, rapid tool wear and breakage of tool are some of the common problems associated with conventional machining methods [2]. Therefore, there comes a need to use advanced technology or non-traditional methods to machine these composites.

Electrical Discharge Machining (EDM) is one of the nonconventional methods used for machining metal matrix composites. It is a noncontact process that makes it well suited for materials that cannot take stress of traditional machining. Drilling is an imperative process to access the structural durability of the composite [3]. Therefore, it is fundamental that the drilled micro sized holes have minimum tolerances and burrs. There comes a need to use light weight nanocomposite materials. Therefore, this experiment is aimed at observing and analyzing process parameters that effect the material removal rate when micro sized holes are drilled in magnesium nanocomposite samples. EDM has been used to drill these micro sized holes since it is a high precision drilling method. Also, EDM is

used in order to ensure minimal surface roughness and burrs.

2. PRINCIPLE OF EDM

An electrical spark is created between the electrode and workpiece. Intense heat with temperatures reaching 8000 to 12000 degrees Celsius is produced by the spark. The material is removed from the workpiece by rapidly occurring spark discharge [4].

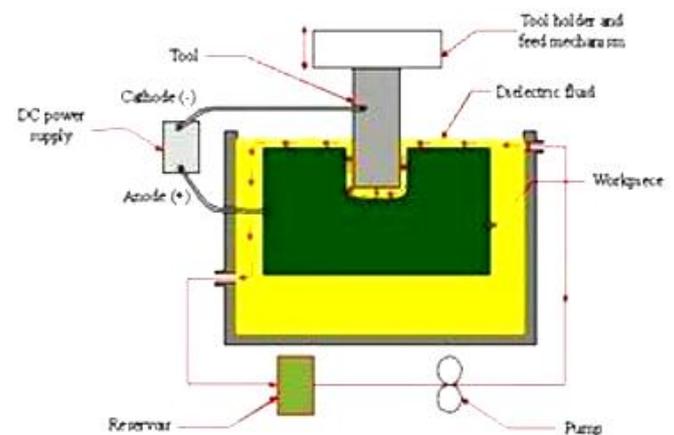


Fig-1 : Machining principle of EDM.

3. EXPERIMENTAL SETUP

The experiment was conducted on ELECTRONICA small-hole super drill ED 32U. The dielectric fluid used is distilled water. Experiments were conducted with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode.

3.1 Selection of tool material

For this experiment brass has been selected as the tool material of diameter 0.5 mm. The reasons for selecting the brass as a tool material are as follows:

- i. High electrical conductivity
- ii. Sufficiently high melting point
- iii. Easily available

3.2 Selection of Work Piece Material

For this experiment, the work material used was magnesium nanocomposites (reinforced with 1.98% and 2.50% Titanium Carbide). It is a lightweight and futuristic material in automotive and aerospace applications due to its attractive properties.

3.3 Selection of Process Parameters

There are many process parameters in EDM like peak current, gap voltage, pulse on time, pulse off time, current density etc. But in this work, gap voltage, pulse on time and pulse off time have been selected as variable parameters. The ranges variable process parameters have been found by conducting the trial runs and from the literature survey.

3.4 Selection of Range of Process Parameters

The process parameters are taken in L9 orthogonal array system.

- i. Current (I): It was maintained at 3 A which is an optimised value to ensure efficient material removal by arcing. The feed rate was optimized at 3 μm/s throughout the experiment so as to prevent burring of hole inner surface.
- ii. Gap Voltage (V): It is a potential difference between the electrode (tool) and work piece. When this gap voltage reaches a sufficient value the discharge takes place and causes significant effect in the MRR of workpiece.
- iii. Pulse on time (Ton): The experiment has been conducted at 5μs, 7μs and 9μs depicting L9 Orthogonal array system. A higher value of Ton causes excessive heating which may cause defect in the workpiece [5]. A lower value reduces machining time, thereby causing a reduction in MRR.
- iv. Pulse off time : The experiment has been conducted at 10μs, 12μs and 14μs. A low value of Toff may cause inconsistent cycling and therefore lead to retraction of the incoming servo or slowing down the operation cycle [5].

The experiments were designed as per Taguchi design of experiments. For each reinforcement, 9 experiments were performed as suggested by Taguchi orthogonal array. The experimental matrices for 1.98% and 2.50% reinforcement of Titanium Carbide are shown in Table 1 and Table 2 respectively.

Table – 1 : Experimental matrix for 1.98%(hole 1-9) and 2.5%(hole 10-18) TiC

Hole no.	Process Parameters		
	Voltage gap	Ton	Toff
1.	2	5	10
2.	4	5	12
3.	6	5	14
4.	4	7	10
5.	6	7	12
6.	2	7	14
7.	6	9	10
8.	2	9	12
9.	4	9	14
10.	2	5	10
11.	4	5	12
12.	6	5	14
13.	4	7	10
14.	6	7	12
15.	2	7	14
16.	6	9	10
17.	2	9	12
18.	4	9	14

3.5 Determination of Material Removal Rate

The amount of metal removed from the workpiece by the electrode for a specific time is known as Material Removal Rate. There is a high temperature spark discharge which causes erosion of metal in the form of a cavity of the electrode shape [7]. It is a desirable characteristic for the MRR to be high to ensure high productivity in low cycle time. It is measured using the following formula [8]:

$$MRR = \frac{Volume(mm^3)}{time(s)}$$

3.6 Signal to Noise Ratio

Traditional and experimental design methods are too complex in determining the most efficient range of parameters. Also, a large number of experimental parameter variables have to be inputted to deliver contrasting results [9]. Therefore, Taguchi method solves this task by using a special design called L9 orthogonal array which consists of a small number of experiments. The S/N ratio can be used derive performance characteristics which depend on the controlled output parameters.

The category selected to study the S/N ratio is “Bigger is better” for MRR. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. The maximum MRR was obtained at the following conditions.

Table-2: Optimum condition for MRR

%TiC	V	Ton	Toff
1.98	4	9	14
2.5	2	9	14

4. EXPERIMENTAL RESULTS AND DISCUSSION

The drilled hole is depicted as shown in Figure 2 with diameter measured using a microscope.

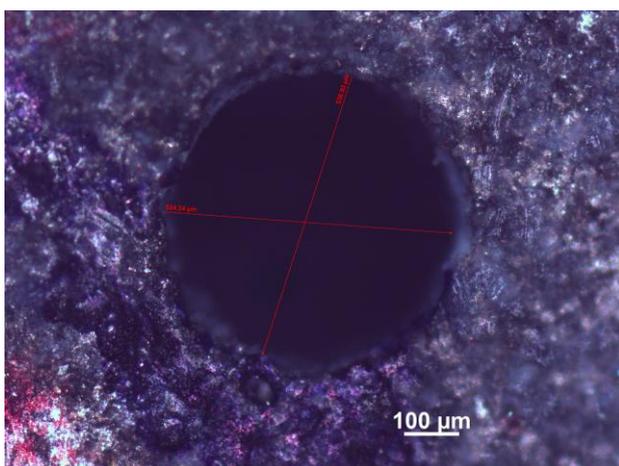


Fig-2 EDM Drilled hole sample

Table-3 : S/N ratio for MRR for 1.98%TiC and 2.5%TiC

1.98%	Voltage gap(V)	Ton(μs)	Toff(μs)
Delta	0.1896	2.9342	0.7391
Rank	3	1	2
2.50%	Voltage gap(V)	Ton(μs)	Toff(μs)
Delta	0.2464	2.5552	0.9245
Rank	3	1	2

4.1 Effect of Input Parameters on MRR

The value of input parameters and output parameters were analyzed using Taguchi method. The rankings given in Table 3, It states the degree of influence by the input parameters on MRR. The results show that Ton has highest significant followed by Toff and voltage for both the reinforcements. The S/N ratio curve for MMR was plotted as a method to visualize varying effect of the input parameters on MRR.

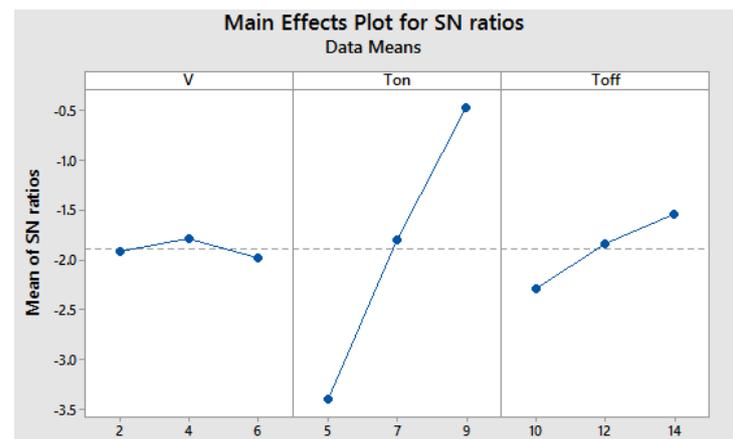


Figure 3 Main Effects Plot for SN ratio for 1.98% TiC

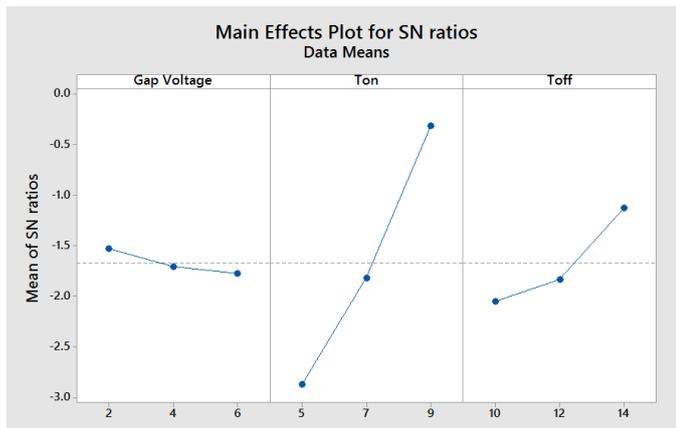


Figure 4 Main Effects Plot for SN ratio for 2.5% TiC

4.1.1 Effect of Pulse on time

It can be inferred from the graphs, the material removal rate increases proportionally with increasing pulse on time [10]. The pulse on time was varied between 5 and 9. The reason for the increased MRR is due to the increased spark energy as the pulse on time increases [11]. It can be also inferred from Figure 3 that changes in pulse on time causes the maximum change in MRR.

4.1.2 Effect of Pulse off Time

The pulse off time is varied between 10 to 14. The material removal rate as inferred from the graph is found to increase steadily from 10 to 12 and then increase at a very low rate from 12 to 14. It is interesting to note that during pulse off time there is no material removal, however the reason for increased MRR is attributed to better flushing of micro debris during long pause time which results in improved MRR [12].

4.1.3 Effect of Voltage Gap

The voltage gap of the corresponding experiments is varied between 2 to 6 V. The Material removal rate is found to increase from 2 to 4 V and then decrease from 4V to 6V for 1.98% TiC reinforcement where as for 2.5% TiC reinforcement it decreases with the increase in volatage for the range od process parameters tested.. The possible reason for the decrease in MRR at high gap voltages is decreased gap current.

5. CONCLUSION

In this paper, micro holes of diameter around 500 μm were drilled in magnesium nanocomposites reinforced with TiC using EDM. The effect of process parameters on MRR have been studied and optimized. The main conclusions from the experimental results are given below:

The MRR increases with the increase on pulse on time for both 1.98% and 2.5% TiC reinforcements. The pulse on time has high significant (I-rank) on MRR. The maximum MRR was obtained at high level of pulse on time.

As the pulse off time increases, the MRR shows increasing trend within the range of investigation. The Taguchi analysis shows that pulse off time has II- rank on the MRR. The maximum MRR was obtained at high level of pulse off time.

The MRR decreases at high gap voltages for both the reinforcements. The maximum MRR was obtained at middle level (4 V) for 1.98% TiC and at low level (2 V) for 2.5% TiC reinforcement. The voltage gap seems to induce a very less change in MRR.

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