Optimization of the Electrical Discharge Machine using AZ 31 Magnesium alloy

Dilip Shyam Prakash Chinnam, N. Ramanaiah, K. Venkata Subbaiah

Abstract: Electrical Discharge Machine (EDM) is the process of designing the material and including complex structure using electrical discharge. Many research has been carried out in the EDM using different materials to increase Material Removal Rate (MRR), decrease Electrode Wear Rate (EWR) and Surface Roughness (SR). The various optimization techniques are applied to identify the parameter settings to increase MRR. In this research, the EDM process is conducted using the material of AZ 31 Magnesium alloy with hydrothermal treatment to reduce the MRR. The Taguchi method is applied to identify the optimal parameter for the EDM process to minimize the MRR, EWR and SR. The optimal value of the method is obtained as peak current of 55 A, voltage of 220 V, pulse on-time of 16 µs, and the pulse off-time of 512 µs.

***Index Terms**: AZ 31 Magnesium alloy, Electrical Discharge Machine, Electrode Wear Rate, Material Removal Rate, and Surface Roughness.*

I. INTRODUCTION

a. OUTLINE

A thermoelectric machining method considered EDM process as a vital method for machining the conductive materials [1]. Through EMD technique, an Aluminum composite fabrication has improved proper stirring in the particle dispersion matrix [2]. A very large features from the machining process to cut materials was difficult in machine and the machine could be used for the large and micro feature [3]. The optimum value of EDM machining parameter such as MRR, SR, and EWR are the dependable parameters [4]. A model could accurately predict the performance by relating these parameters even though the EDM process is complicated and difficult to understand the needs [5].
The difficulty faced in the conventional process is due to the upgraded materials that possess dominant properties for improvising the hardness [6]. Between the work piece and the electrode, a huge electric potential difference is developed in the dielectric medium that generates plasma channel and the work piece material is melted [7]. To improve process performance such as MRR in EDM process many researches are investigated and have been attempted for modelling [8]. By decreasing the MRR and the surface quality of materials are still the challenging problems that limits the application [9,10]. In this research, the material of AZ 31 magnesium alloy is used for EDM optimization process. The orthogonal array technique is used to find the optimal parameter setting, which is measured to reduce EWR, Surface roughness and increase the MRR.
The paper is formulated as related works in the section II, experimental setup is explained in the section III, result and discussion is provided in the section IV. The conclusion of the paper is given in section V.

II. RELATED WORKS

The recent research in the EDM of different material optimization techniques were discussed in this section.

Paras Kumar and Ravi Parkash [11] investigated the process parameters for examining the effect of EDM on performance evaluation such as MRR, EWR, and SR during of Aluminum Boron Carbide (Al–B4C) composite machining. The developed method used 5% B4C particles of 50-micron size in Al 6061 where the Metal Matrix Composites (MMC) was used. For designing the experiments (L9-orthogonal array), Taguchi technique was used for the experiments whereas the results were validated through ANOVA. The limitation of the developed method required increase in the performance values for different material was needed to be applied.

Khullar et al. [12] studied the machining characteristics of EDM for distinct methods for flushing. The EDM performance was investigated and AISI 5160 alloy steel was used. The most important factors such as MRR and SR were selected for computing the influence of factors. The Non-Dominating Sorting Genetic Algorithm II (NSGA-II) solved the mathematical models. The limitation of the developed method required effectiveness for increase in MRR and SR measures.

Mathan Kumar, et al. [13] tested the four input parameters namely: pulse on-time, pulse current, diboride percentage and flushing pressure to evaluate MRR and Tool Wear Ration (TWR). The developed regression model adequacy is tested based on the ANOVA test. The desirability based multi-objective optimization is applied to identify the optimal parameter value for the increase MRR and decrease TWR.

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The optimum parameter is obtained as titanium diboride of 16%, pulse current of 6 A, pulse on-time of 35 μs and flushing pressure of 1 Mpa. The experiment was conducted to confirm the response surface model. The SR is high and need to be reduced. Rengasamy, et al. [14] developed Aluminum 4032 MMC with reinforcement particles Zirconium Boride (Zrb2) and Titanium Boride (Tib2) in various Wt. % (0, 2, 4, 6, 8) using the stir casting method.

The reinforced particles influence the mechanical particle and parameter such as MRR, depth in process of EDM and TWR. The copper electrode is used and factors like Pulse OFF (ms), Pulse ON (ms) and current (Amps) is applied to start the process. The ANOVA was applied to evaluated the parameter influence in the experiment. The optimization technique can be applied to increase the performance of the method.

Prakash, et al. [15] developed the method involves in the hydroxyapatite coats with the pores. The coating is made in the surface of Mg-Zn-Mn alloy using hydxroxyapaptite (HA) powder mixed with EDM process. The method is optimized based on the Multi-Objective Particle Swarm Optimization (MO-PSO) technique to identify the optimum level of hydroxyapatite powder (CH) concentration, Pulse-on, Pulse-off and peak-current. The XRD pattern investigates the modified surface, which provides the formation of various biocompatible phase that enhance the mechanical properties, corrosion and osseintegration characteristics. The various material is need to be tested for decreasing the SR.

III. EXPERIMENTAL SETUP

The experiments are processed using the die sinking type EDM with servo control system. The machine has the 9 settings of Pulse-on time, 9 settings of the Pulse-off time and 6 current settings from 1 to 10 A. The electrode polarity is set as negative, while work-piece as positive. EDM provides the electrode into the work piece to process and validate the electrode spacing and control for proper arc gap. The dielectric tank connected with dielectric pump, a filter system and an oil reservoir. The electronic balance weight machine is applied to calculate the MRR and EWR.

A. Fabrication of AZ 31 Magnesium alloy

A solution of heat-treatment was applied at 450°C for 1 min in room temperature water to prepare the first set of coupons with single phase and fine recrystallized grains. The chemical composites of material: Al is 3%, Zn is 1%, Mg is present in remaining percentage. The AZ 31 work pieces are cut into rectangular cross-sections of dimension 51 mm × 51 mm × 12.7 mm. The top and bottom of the piece are made as flat and good surface finish before the experiment. The electrode material used in the experiment of the work piece are of cylindrical shape of diameter 30 mm. The machining is conducted for 20 min for all the experiments. The fabrication of the Mg(OH)2 is similar in the research [16].

B. Design of Experiment using Taguchi Method

Taguchi method is applied to reduce the variation in process through the robust design of experiments. The orthogonal array L_g are applied to validate the parameters influence in the EDM process and the level factors should be varied. Only necessary data are collected to measure the parameter influence that are most affecting the result with minimum number of experiment, thus saving time and resources. The Taguchi method are applied to identify the optimal parameter values to optimize the performance characteristics.

Table I.The parameter value in three level

Parameter	Peak current	Voltage	Pulse on-time	Pulse off-time
Level 1	38 A	80 V	16 μs	128 μs
Level 2	47 A	220 V	32 μs	256 μs
Level 3	55 A	320 V	64 μs	512 μs

There were nine EDM experiment is conducted with varying three levels [17] of four parameter values, as given in Table 1. The orthogonal array of experiment for the various parameter process are shown in Table 2. Parameter values are used based on the suggestions of user manual provided for the machine. Each experiments were repeated three times to ensure data accuracy. The AZ 31 Magnesium alloy are used in this experiment and this is suitable for the temporary implant application and copper is used as EDM electrode. A constant cutting depth of 2 mm is maintained through-out the experiment. The SR tester is used to measure the SR at the three different locations on each specimen. Optimum EDM parameter for smoothest surface were obtained using Taguchi method and validated using confirmation test.

Table II. The orthogonal array of the AZ 31 Magnesium alloy

Experiment	Peak Current (A)	Voltage (V)	Pulse on-time (μs)	Pulse off-time (μs)	Average MRR	Average EWR	Average SR
1	38	80	16	128	14.2	0.72	8.026
2	38	220	32	256	5.62	1.71	9.62
3	38	320	64	512	6.2	0.624	14.24
4	47	80	32	512	80.27	0.961	8.26
5	47	220	64	128	32.63	0.528	12.15
6	47	320	16	256	7.82	1.862	8.12
7	55	80	64	256	137.2	2.86	15.85
8	55	220	16	512	138.25	0.942	7.24
9	55	320	32	128	22.35	1.25	10.83

IV. RESULTS AND DISCUSSIONS

The objective of the research is to find the parameter for AZ 31 magnesium alloy material to increase the MRR, decrease the EWR and SR. The parameter related to these three attributes are validated based on the Orthogonal array method. This provides the optimal value for the machining parameter to increases the MRR, decrease EWR and SR. The parameter influence on the three output is tested in this section. The mean of means output of MRR, EWR and SR is measured for each parameter to tested its influence on the output.

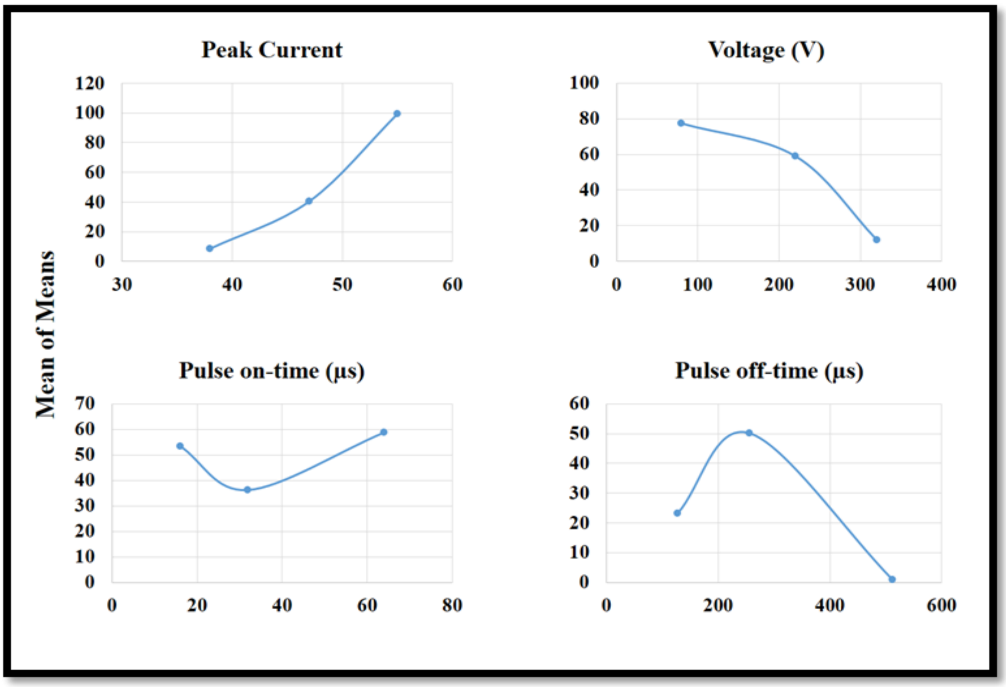

Fig. 1. The parameter influence on the MRR

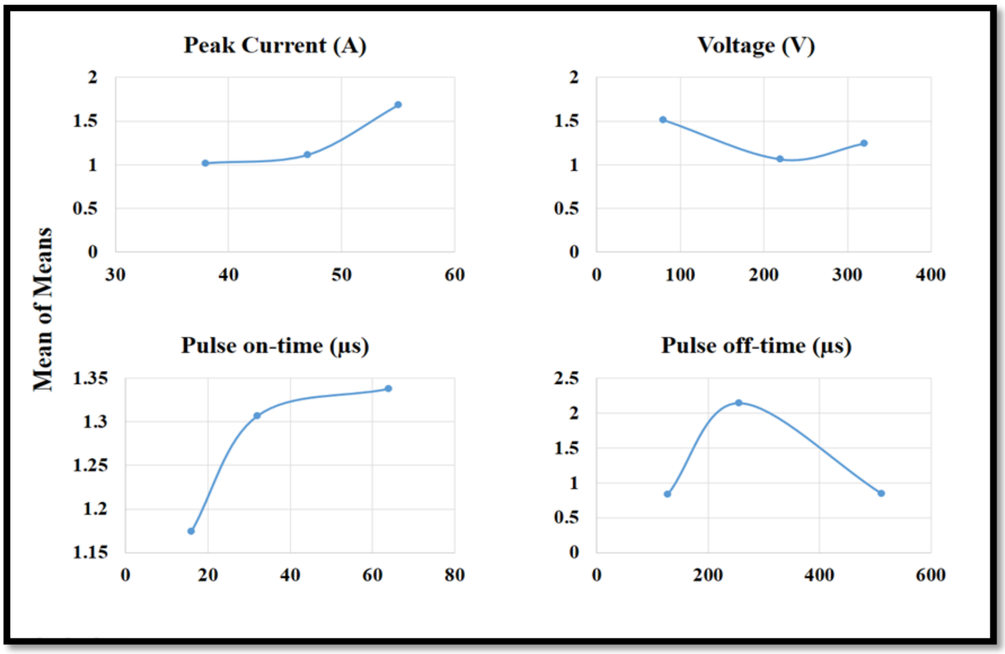

Fig. 2. The parameter influence on EWR

The four parameter influence on the MRR is shown in Fig. (1) based on the Mean of means value. The peak current is increases that increases the MRR and peak current of 40.24 has the MRR of 40.24. The lower voltage provides higher MRR and the voltage of 80 V has the MRR of 77.22. The pulse on-time in the 32 µs has the MRR of 36.08 and the more pulse on-time has increases the MRR. The pulse off-time of 256 µs has the MRR of 50.21 and this provide the more MRR.

The parameter influence on EWR is validated and shown in Fig. (2). The increase in Peak current increases the MRR and the peak current of 47 A has the EWR of 1.117. The increase in voltage decrease the EWR and the voltage of 320 V has the EWR of 1.24.

The pulse on-time increases the EWR and the pulse on-time of 32 µs has the EWR of 1.307. The increase in the pulse off-time decreases the EWR and the pulse off-time of 512 µs has the EWR of 0.84.

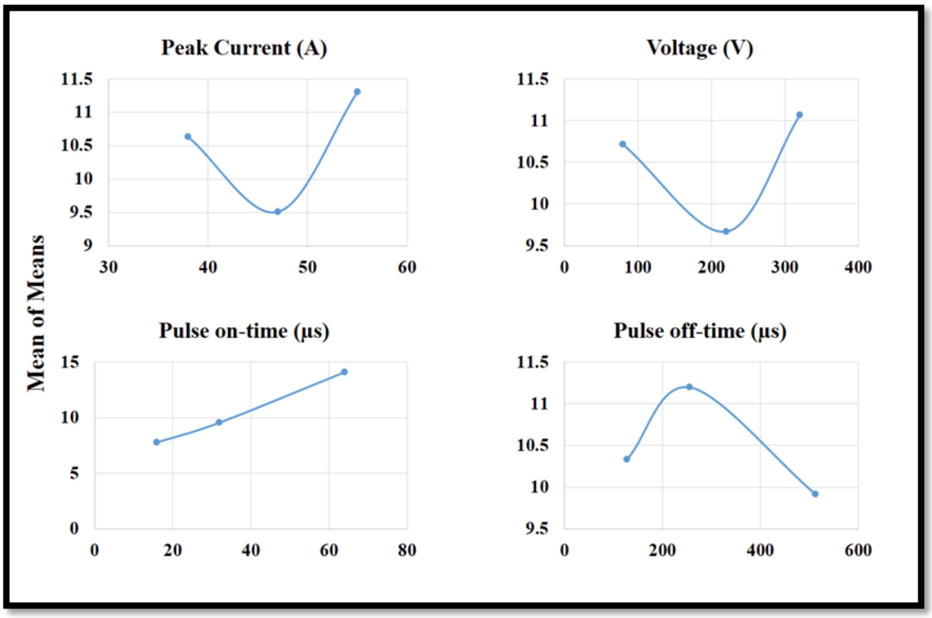

Fig. 3. The parameter influence on Surface roughness

The parameter influence on SR is shown in Fig. (3) based on the Mean of means value. Fig. (3) shows the peak current parameter influence on the SR and the peak current of 55 A has the SR of 11.3 µm. The voltage of the machine affects the SR and the voltage of 220 has the lower SR of 9.67 µm. The increase of pulse on-time increases the SR of the material and the pulse off-time of 32 µs has the lower SR of 9.57 µm. The pulse off-time of the machine has affect SR and the pulse off-time of 512 µs has the SR of 9.91 µm.

The optimal value for the EDM of AZ 31 magnesium alloy has peak current of 55 A, voltage of 220 V, the pulse on-time of the 16 µs, and the pulse off-time of the 512 µs provides the MRR of 138.25, the EWR of 0.942 and SR of 7.24 µm.

V. CONCLUSION

The complex structure of materials is fabricated using EDM process by different materials. In this research, the material of AZ 31 Magnesium alloy is used to fabricate the component to evaluate the performance of the material and machining. The orthogonal array technique is applied to identify the optimal value for the machining. The three level of parameter setting to increase the MRR, decrease the EWR and SR. Furthermore, the parameter influence on the MRR, EWR and SR is also measured. The multi-objective is considering in this method to increase the MRR, decrease the EWR and SR. The optimal value to increase the MRR, decrease EWR and SR is peak current of 55 A, voltage of 220 V, pulse on-time of 16 µs, and the pulse off-time of 512 µs. In the future work, the AZ 31 magnesium alloy material is coated with composites to increase the surface finish.

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