Optimization of process parameter for magnesium alloy processed in wire-cut EDM

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Abstract

Since last decade wire-cut EDM is emerging technology for machining process of magnesium in various industries like automobile, aerospace, medical field which used to manufacture intricate shapes with great accuracy and good surface roughness. In this investigation, material removal rate and surface roughness of magnesium AZ31 by different process parameter of wire-cut EDM. The process parameters (Pulse-on time, Pulse-off time, Peak current, Servo voltage) are analysed and optimized by the Taguchi method. After that the optimized material removal rate has 81.84% significant to peak current and surface roughness has 72.05% significant to pulse-on time.

Keywords: Pulse timing; Current and voltage; Material removal rate; Surface roughness; SEM.

1. INTRODUCTION

Mg composites as the lightest basic materials in modern application have low density (*1.8 g/cm*^{3}), high young's modulus (*42 GPa*), high specific strength, stiffness, excellent damping property, machinability and great dimensional stability widely applied in industries, aerospace, automobile, hardware and household apparatuses [8]. As per the attributes of its crystal structure, pure magnesium can't meet some particular necessities. The different alloys turn into a significant factor that decides the properties of magnesium. Tensile strength of magnesium AZ31 has 185-230 MPa and melting point temperature has 650 °C [4].

Magnesium alloy is a biocompatible material that can be utilized as transitory biomedical implants. The human body contains 35 g magnesium per 70 kg body weight. During the machining procedure on magnesium alloys utilizing traditional strategies, for example, milling, turning and boring which develops the cracks, built-up edge, and chatter on the surface. Therefore, the non-conventional machining process like wire-cut Electric Discharge Machining as best and particularly to create unpredictable shapes with close tolerance. In this research, the plan of the experiment and the outcome is analysed using the Taguchi method.

Subrahmanyam and Nancharaiah [1] showed that investigation of process parameter of wire-cut EDM on Inconel 625. Pulse-on time, Pulse-off time, Servo voltage is taken as process parameters and the reaction parameters watched are material removal rate and surface roughness. It's shows that process parameters of pulse-on time and pulse-off time has influenced nearly 61.90 % on MRR and 67.09 % on SR.

Singh et al. [2] calculated an investigate the effect of the process parameters on MRR during wire-cut EDM of Al6063 composite. It represents that MRR increase while develop the pulse-on time,

which increasing pulse-off time and servo voltage while decrease the MRR.

Kavimani et al. [3] calculated an experiment on graphene-SiC-magnesium composite machined on wire-cut EDM. In this work the machining parameters (Pulse-on time, Pulse-off time and WF) have been chosen for their effects on the desired output response (MRR and Ra). This experiment results that expanding the term of pulse-on time and WF in wire-cut EDM to increase the MRR.

Patel and Maniya [9] showed that surface integrity investigates of Nimonic 80A alloy utilizing wire-cut EDM. T_{on}, T_{off}, IP, WF, WT, and SV are input parameters and the yield reactions by MRR, SR and wire wear ratio. It's drawn that trim cut machining forms, T_{on} has found for the major influencing variable of the MRR (52.31 %) and SR (74.69 %).

2. EXPERIMENTAL PROCEDURE

The experimental work has been done on wire-cut electric discharge machine. This machine arrangements have four significant sub-components to be a power supply unit, dielectric unit, positioning unit, and drive unit. The power supply unit consist of DC high voltage transmission circuit. Dielectric unit consist of de-ionized water reservoir, filtration system, pumping system. The positioning unit is made up of two automated numerical control tables. It works in a versatile control mode so that on the wire arrives at nearer to the workpiece, or the gap is crossed over by debris and causes a short circuit, the positioning unit competent to detect it. The drive unit continuously driving the new wire, and continually holding the wire tension with the goal that it moves in the machining zone as a straight wire. Additionally, it helps in limiting wire break, taper, streaks just as vibration marks [2]. Analyses were performed on a wire-cut EDM machine design while fixed section, moving table set with a size of 250 × 350 mm, power supply 3 phase, AC 415 V, 50 Hz. The 0.18 mm diameter of molybdenum wire as to be used for cutting tool while de-ionized water was used as a coolant. In this experimental work magnesium AZ31 alloy has been chosen as the workpiece material to its commercial and industrial importance in the aerospace industry, medical implants, automobile industries, etc. The process parameters impact the wire-cut EDM procedure are extensively arranged in three categories: power supply related: type of supply, current, voltage, pulse times; wire related: wire type, wire material, size of wire; workpiece related and others: workpiece material, machining time, machining region. Right now, on schedule, pulse on time, pulse-off time, peak current and servo voltage are utilized as input parameters.

Fig-1 Machining pieces

Aside from the process parameters and their values has been selected for machining work, they were kept consistent during the trial work.

1. Work material : Magnesium AZ31
2. Wire feed : 5.74 mm/min
3. Wire diameter : 0.18 mm

If cutting range as to be followed by table-1 while nine cutting pieces their size of 10 mm × 10 mm.

Table-1 Parameter range

S.No.	Parameter	Range
1	Pulse-on time (P_{on})	65-75 µs
2	Pulse-off time (P_{off})	24-30 µs
3	Peak current (IP)	2-4 A
4	Servo voltage (SV)	20-25 V

Table-2 Levels of parameter

Parameter	Level-1	Level-2	Level-3
Pulse-on time (P_{on})	65	70	75
Pulse-off time (P_{off})	30	26	24
Peak current (IP)	2	3	4
Servo voltage (SV)	20	22	25

3. RESULTS

3.1. MRR Calculation

During the machining process, the spark will be produced. The spark developed the high-temperature which causes the melted or vaporize the material from workpiece. This vaporized material can be calculated by,

$$MRR = k \times t \times F.R \times \rho \qquad \ldots(i)$$

Where,

MRR - Material removal rate in g/min

k - Kerf in mm (*0.18 mm*)

t - Thickness of workpiece in mm (*6 mm*)

F. R - Cutting speed in mm/min

ρ - Density of workpiece g/cm^3

The material removal rate has been calculated by using equation (i),

1. MRR = 0.18 × 6 × 148.7 × 1.8 = 0.2890 g/min
2. MRR = 0.18 × 6 × 152.8 × 1.8 = 0.2970 g/min
3. MRR = 0.18 × 6 × 156.7 × 1.8 = 0.3046 g/min
4. MRR = 0.18 × 6 × 154.2 × 1.8 = 0.2998 g/min
5. MRR = 0.18 × 6 × 153.9 × 1.8 = 0.2992 g/min
6. MRR = 0.18 × 6 × 150.1 × 1.8 = 0.2917 g/min
7. MRR = 0.18 × 6 × 157.6 × 1.8 = 0.3064 g/min
8. MRR = 0.18 × 6 × 151.0 × 1.8 = 0.2935 g/min
9. MRR = 0.18 × 6 × 155.1 × 1.8 = 0.3015 g/min

Table-3 Material removal rate values

S. No	P_{on} (µs)	P_{off} (µs)	IP (A)	SV (V)	FR	MRR (g/min)
1	65	30	2	20	148.7	0.289
2	65	26	3	22	152.8	0.297
3	65	24	4	25	156.7	0.3046
4	70	30	3	25	154.2	0.2998
5	70	26	4	20	153.9	0.2991
6	70	24	2	22	150.1	0.2917
7	75	30	4	22	157.6	0.3064
8	75	26	2	25	151	0.2935
9	75	24	3	20	155.1	0.3015

From the table-3, the pulse timing and peak current is more contribute factor to material removal rate. Particularly the pulse-on time and peak current while increase their material removal rate is always increase.

3.2. Surface roughness

Surface roughness values carried out by using surface roughness tester (Mitutoyo SJ-201). These experiments, the surface roughness values as displayed on the surface roughness tester. From table-4, pulse on time is having the highest significant factor to surface roughness.

Table-4 Surface roughness values

S.No	P_{on} (µs)	P_{off} (µs)	IP (A)	SV (V)	SR (µm)
1	65	30	2	20	3.124
2	65	26	3	22	3.195
3	65	24	4	25	3.309
4	70	30	3	25	3.211
5	70	26	4	20	3.659
6	70	24	2	22	3.853
7	75	30	4	22	3.721
8	75	26	2	25	4.008
9	75	24	3	20	4.12

3.3. Scanning electron microscope

The surface integrity (that means microstructure or surface morphology) has investigated by using scanning electron microscope, while after the machining process. Fig-2 shows that smooth surface obtained by the parametric setting of; pulse-on time: 65 µs, pulse-off time: 30 µs, peak current: 2 A, servo voltage: 20 V. Fig-3 shows the rough surface, because the high energy discharged on the surface by the parametric setting of; pulse-on time: 75 µs, pulse-off time: 24 µs, peak current: 3 A, servo voltage: 20 V.

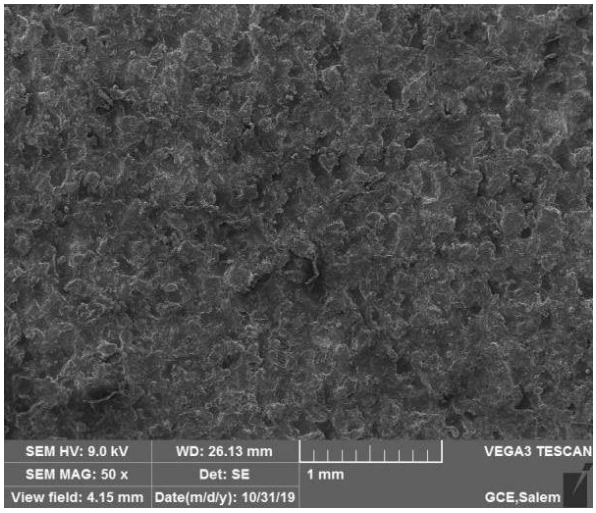

Fig-2 Without machining surface

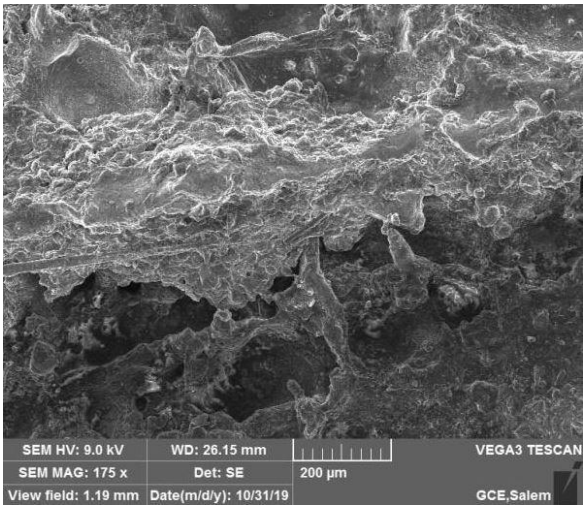

Fig-3 Machining surface

4. DISCUSSION

4.1. Optimization technique

The orthogonal designs can be utilized to pertinent two-level factorial assessments as well as can explore fundamental impacts when variables have multiple levels [1]. The Design of tests is led utilizing Taguchi's technique where the quantity of parameters is three with three degrees of every parameter having the principal level a lower limit and the subsequent level as middle of as far as possible and the third level is as far as possible for that variable. There are numerous standard orthogonal arrays from which required one can be chosen dependenting on different conditions.

The outcomes got from the trials were investigated utilizing analysis of variance to discover the significance of each input factor on the proportions of process performance, material removal rate and surface roughness. ANOVA is formulated for identifying significant factors. The percentage contribution of each parameter is calculated and the maximum contribution is observed.

General linear model MRR versus P_{on}, P_{off}, IP

The higher estimated value of F-ratio shows that any little variation of the procedure parameter can make a noteworthy impact on the performance characteristics. An increase in servo voltage builds MRR, from table-5 shows the main impacts plot for MRR versus pulse-on time, pulse-off time, servo voltage. As per this, peak current is seen as the hugest factor influencing of MRR. The material removal rate has 81.84 % significant to peak current.

General linear model SR versus P_{on}, P_{off}, IP

Table-6 shows the results for SR where pulse-on time found to be a significant factor with a 72.05 % contribution. Its shows increasing pulse-on time while increase the surface roughness. Because the longer pulse duration, which leads to discharge high energy. Its causes to remove more material from the work piece.

Table-5 Analysis of variance for MRR

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Pon	2	0.000026	9.50%	0.000026	0.000013	2.18	0.314
Poff	2	0.000012	4.29%	0.000012	0.000006	0.98	0.504
Ip	2	0.000223	81.84%	0.000223	0.000112	18.78	0.051
Error	2	0.000012	4.36%	0.000012	0.000006		
Total	8	0.000273	100%				

Table-6 Analysis of variance for SR

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Pon	2	0.82219	72.05%	0.82219	0.4111	34.15	0.028
Poff	2	0.25879	22.68%	0.25879	0.1294	10.75	0.085
Ip	2	0.0361	3.16%	0.0361	0.01805	1.5	0.4
Error	2	0.02407	2.11%	0.02407	0.01204		
Total	8	1.14115	100.00%				

5. CONCLUSIONS

The energy supplied into the discharge gap is dependent upon voltage and current. Hence, increases in either of the parameter increase in MRR. From the ANOVA analysis, it is evident that out the input parameter, peak current is having the highest significant factor (81.84 %) to material removal rate. For surface roughness, which pulse on time and pulse off time are significant factors. Pulse on time has the most elevated factor of surface roughness. From the ANOVA analysis, it is evident that out the input parameter, pulse on time is having the highest significant factor (72.05 %) to surface roughness. SEM images have to denote the effect of a surface morphology by temperature difference and crack formation details. The wire-cut EDM has a better surface finish without cracks on machining surface compared with the electric discharge machine.

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