INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 4 Issue 2 – www.ijrmmae.in – Pages 11 - 18

OPTIMIZATION OF MAGNESIUM ALLOY AZ31 USING WIRE ELECTRICAL DISCHARGE MACHINING

SARAVANAKUMAR.C[1], R.GOPINATH[2], I.SATHAM HUSSAIN[3]

[1,2,3] **Assistant Professor, Dept. of Mechanical Engineering, Dhanalakshmi Srinivasan College of Engineering, Tamil Nadu, India**

[a] e-mail: csaravana.csk@gmail.com, [b] e-mail: gopiravi008@gmail.com, [c] e-mail: drsatham@dsce.ac.in

Abstract

Electrical discharge machining (EDM) is a electro thermal unconventional process in which material removal occurs due to the spark generation between the tool and work piece in the presence of dielectric fluids. Wire-Electrical discharge machining is one of the advanced methods of EDM, where a wire is used as an electrode. The distinctive advantage of Wire-EDM is producing components of Automotive, Aerospace and surgical equipment's. Magnesium Alloy (AZ31) is a one of the light material which has significantly used in those areas. This paper deals with the experimental investigation and optimization of various parameters for the Wire-EDM on Magnesium alloy (AZ31). Nine experiments were conducted using Taguchi method with three levels and four factors on magnesium alloy to explore the optimum conditions for Material removal rate (MRR) and Surface roughness (SR). It was found that pulse on-time was the most influential parameter that affecting the both MRR and SR, followed by Voltage.

Keywords: Electrical Discharge Machining, Magnesium Alloys, MRR, Surface Roughness

1. Introduction

In this era, manufacturing industries are facing various challenges from advanced machine materials, like super alloys, ceramics and composites with various requirements and machining costs. There is also the need of reducing weight and using less energy trend is growing, so we have to use light weight and compact mechanical components. In the modern era, the new concepts of using nonconventional sources are getting improved. These processes are Non-conventional means of that they do not use the traditional tools for metal removing processes instead they use other energy forms. For the last few years Electrical Discharge Machining (EDM) plays a bigger role to machine the advanced materials with desired shape, size and with accuracy. It is a non-conventional process, where electrically conductive materials is machined by precisely controlled sparks that occurs between an electrode and work piece with the presence of a dielectric field.

WIRE-Electrical Discharge Machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult to machine by conventional machining processes. Its unique feature of using thermal energy to machine electrically conductive parts has been its distinctive advantage in the manufacture of mold, die, automotive, aerospace and surgical components. Many researchers tried to optimize the machining performance by adapting different optimization techniques. At the present time, WIRE-Electrical Discharge Machine (EDM) is a widespread technique used in industry for high precision machining of all types of conductive materials such as: metals, metallic, alloys, graphite or even some ceramic materials of what so ever hardness. Electrical Discharge machine technology is increasingly being used in tool, die and mould making industries for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish. WIRE- Electrical Discharge machining actually is a process of utilizing the physical phenomenon of electrical-discharge in dielectric. Therefore the electrode plays an important role, which affects the material removal rate and tool wear rate. Research and development of magnesium alloys in various field of applications were concentrated on studying properties in order to improve the performances in those applications. For the machining of magnesium alloys the Wire- EDM process is chosen because of its unique characteristics. All the research trends of EDM and Wire-EDM were reviewed and also the influence of the various important parameters also studied in order to select for the objective of the improving the capability of machining performance and better output responses. Magnesium cannot easily machined using Conventional machining process due its low melting point and its nature of easily flammable. So there is need of moving onto the non-traditional processes, such as Wire-EDM. There is not much research were going on the Machining of magnesium alloys. **L.ARUNKUMAR ET.AL (2008)** investigated the machining capabilities of magnesium MMC in the EDM process. In this paper he suggested that peak current and pulse on time are the most dominant parameters. **LIN AND WANG (2010)** optimized quality characteristics of WEDM via Taguchi method based grey analysis for Mg alloy. The input variable such as wire feed rate, pulse on time, no load voltage, pulse off time, servo voltage and wire tension was selected. Surface roughness was response variable of the WEDM machining. L18 array was selected for DOE. The author concludes pulse on time and servo voltage is very much significant in SR**. K.PONAPPA ET AL.(2010)** have chosen pulse on time, pulse off time, voltage and servo speed as input parameters and this paper provides servo speed and pulse on time are the most influential parameters in the Surface roughness. **VIBHU SHARMA ET AL.(2013)** In this study, an effort is made to obtain the effect of the input parameters such as pulse on time, pulse off time and wire feed and servo voltage in WEDM process for the Magnesium alloy (AZ91). These factors play a significant role on the response characteristics of the machine such as MRR and % DD. In the design of experiment, Taguchi method was used to evaluate the optimum input parameters combination for the maximum MRR and minimum % DD. **F. KLOCKE AND M. SCHWADE et al.(2011)** In this paper the influence of the EDM process on the biocompatibility of magnesium samples was investigated. For this purpose SEM and EDX-analysis of WE43 surfaces were performed. In case of Wire-EDM rough cuts only very little foreign material originating from the used electrode was detected on the machined Surfaces. From this paper we can identify that the magnesium alloys can be machined with the help of EDM machines and they possess good surface quality and surface integrity for

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 4 Issue 2 – www.ijrmmae.in – Pages 11 - 18

various applications. In this present work the W- EDM of magnesium alloy for the Bio-medical application was done. **KLOCKE AND M. SCHWADE et al. (2011**) Wire Electro Discharge Machining is capable of machining magnesium alloys efficiently and with good surface integrity. In conclusion EDM is capable of machining the biomaterial magnesium efficiently without damaging the surface layer in a significant manner using trim cuts and up to date generator technology. But further investigations are needed to determine the dominant material removal mechanism during the machining of magnesium to identify relevant process parameters for a material specific optimization. Even though there is an EDM process for the machine the Mg alloy, also in the need of optimize the parameters for the machining of the Mg alloy. **M.A. RAZAK AND A.M. ABDUL-RANI et al.(2016)** Due to limitations in conventional machining methods, non-traditional machining method such as electrical discharge machining(EDM) die sinking process is proposed to produce intricate shape with tight tolerance on magnesium alloy. Nine EDM experiments with three levels and four parameters were conducted using Taguchi method on AZ31 magnesium alloy to explore the optimum machining parameters there are three important points can be drawn. Firstly, among four EDM parameters, the most significant effect to the Ra was pulse on-time and followed by pulse off-time.

2. Experimental Setup

The ELECTRONICA –sprint cut(734) Wire EDM (WEDM) was used to carry out the experiments. The Magnesium alloy (AZ31) chosen as work piece material for the experiments. The chemical composition of the magnesium alloy (AZ31) is given in table 1. The shape was machined by the WEDM with 15*10*5. In the WEDM process Brass wire was used to machine the Magnesium alloy. Table illustrates the properties of wire electrodes. De ionized water was selected as the dielectric for experiments, which is always used for WEDM.

In this work, the effect of four factors was studied. These parameters and their levels are listed in table. Some parameters are fixed constant in order to optimize the result. These machining Parameters chosen based on the literature review.

Element	**%**
Mg	96
Al	2.5 to 3.5
Zn	0.7 to 1.3
Si	0.05
Mn	0.2
Cu	0.05
Fe	0.005
Ni	0.005

Table 1 chemical composition of magnesium alloy (AZ31)

3. Methodology

Taguchi method involves reducing the variation in a process through robust design of experiments. This method uses orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Only necessary data collected to determine which factors are most affecting the result with minimum number of experiment, thus saving time and resources. New parameter values to optimize the performance characteristic can be obtained by analysing data using Taguchi approach. In general, Taguchi method involves steps as follows:

- Determine the process objective and parameters affecting the process.
- Create orthogonal arrays for the parameter design.
- Conduct the experiments.
- Complete data analysis to determine the effect of the different parameters on the performance measure.
- Predict the optimum parameters and conduct a confirmation test.

There were nine EDM experiments conducted with three levels and four parameters as indicated in Table 2. The orthogonal array for the experiment is shown in Table 3. Parameter values as suggested in literature were used in the experiments. Work piece material used in this research was AZ31 magnesium alloy which was suitable for aerospace and automobile applications, while Brass wire was chosen as EDM electrode. Surface roughness was measured and analyzed using Mitutoyo SV3000 Surface Roughness Tester at three different locations on each specimen. The cutting speed values which are displayed on the monitor of the machine tool are taken for the calculation of MRR using the following Equation.

$$MRR = V_C * b * h \ mm^3/min$$

Where, 'V_C' is cutting speed in mm/min, 'b' is width of cut in mm, 'h' is the height of the work piece "b" is width of cut in mm, 'h' is the height of the work piece.

Parameters	Level 1	Level 2	Level 3
Peak current	12	14	16
Voltage	30	35	40
Pulse on time	16	32	48
Pulse off time	114	116	118

Exp.	Peak current (A)	Voltage (V)	pulse on Time (µs)	Pulse off time (µs)
1	12	30	16	114
2	12	35	32	116
3	12	40	64	118
4	14	30	32	116
5	14	35	64	118
6	14	40	16	114
7	16	30	64	118
8	16	35	16	114
9	16	40	32	116

Table 3.Orthogonal array for the experiments

4. Results and Discussion

Data taken from the experimental results are shown in the table 4. Averages of three experiments are taken as output responses for the measurement of surface roughness and the average value is given in the table. Experiment 3 provides the lower surface roughness and experiment provides higher surface roughness. MRR of the material is measured with the help of the formula, and the values are given in the table. Experiment 4 provides higher MRR and experiment 5 gives lower MRR.

Experiment	Peak current(A)	Voltage(V)	pulse OnTime(µs)	Pulse off time(µs)	MRR (mm^3/min)	SR
1	12	30	16	114	4.209	3.827
2	12	35	32	116	3.843	4.001
3	12	40	64	118	3.660	3.178
4	14	30	32	116	4.578	3.800
5	14	35	64	118	3.111	3.243
6	14	40	16	114	3.294	3.396
7	16	30	64	118	4.026	3.490
8	16	35	16	114	4.392	3.091
9	16	40	32	116	3.447	3.995

Table 4. Experimental results of the parameters

Graph for main effects of data means is shown in Fig 1. and the response of mean is shown in Table . The most significant parameter is pulse off time and followed by Voltage. Optimum condition for smaller-is- better was selected from lowest mean value from each parameter which is A2, B2, C3 and D3.The signal to noise ratios for smaller-is- better were derived from Taguchi loss

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 4 Issue 2 – www.ijrmmae.in – Pages 11 - 18

function as shown in equation. Main effect plot for signal to noise ratios is shown in Fig2. and the response for signal to noise is shown in Table 5.

$$SN_s = -10\log\left[\frac{\sum_{i=1}^{n} y_i^2}{n}\right]$$

Table 4.response table for means

Level	current	Pulse on time	Pulse off time	voltage
1	3.669	3.709	3.438	3.688
2	3.480	3.445	3.932	3.629
3	3.525	3.523	3.304	3.356
Delta	0.189	0.261	0.628	0.332
Rank	4	3	1	2

Table 5. Response Table for Signal to Noise Ratios Smaller is better

Level	current	Pulse on time	Pulse off time	voltage
1	-11.45	-11.37	-10.69	-11.30
2	-10.81	-10.69	-11.89	-11.17
3	-10.90	-10.90	-10.37	-10.48
Delta	0.44	0.68	1.52	0.82
Rank	4	3	1	2

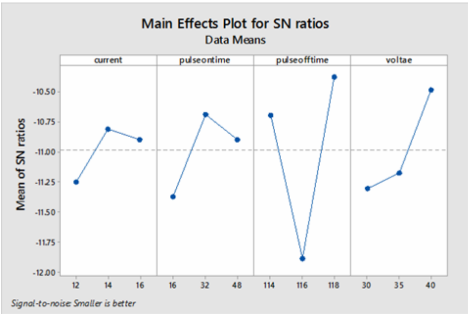

Fig. 1 main effects plot for means

Fig. 2 main effects plot for SN ratios

For MRR, Graph for main effects of data means is shown in Fig 3. and the response of mean is shown in Table 6 . The most significant parameter is pulse on time and followed by Voltage. Optimum condition for larger-is-better was selected from highest mean value from each parameter which is A3, B1, C1, D3 .The signal to noise ratios for-is- better were derived from Taguchi loss function as shown in equation. Main effect plot for signal to noise ratios is shown in Fig. 4.

Table 6. Response Table for Means

Level	Current	Pulse on time	Pulse off time	voltage
1	3.904	4.271	3.965	3.589
2	3.661	3.782	3.596	3.721
3	3.955	3.467	3.599	4.210
Delta	0.294	0.824	0.366	0.621
Rank	4	1	3	2

Table 7. Response Table for Signal to Noise Ratios Larger is better

Level	current	Pulse on time	Pulse off time	voltage
1	11.82	12.60	11.90	1.03
2	11.14	11.47	11.89	11.38
3	11.90	10.79	11.08	12.45
Delta	0.76	1.81	0.82	1.42
Rank	4	3	1	2

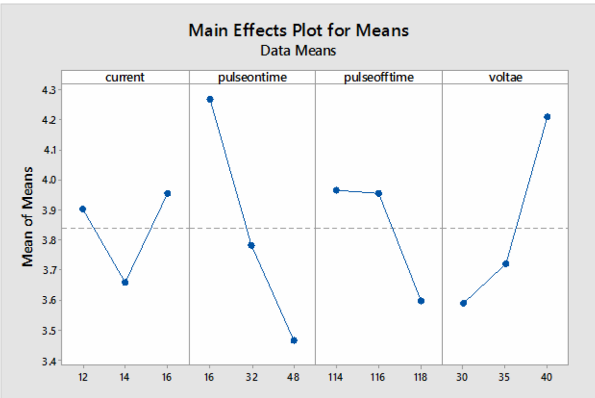

Fig. 3 main effects plot for means

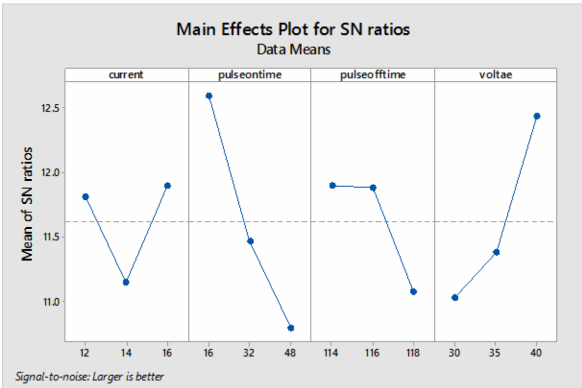

Fig. 4 main effects plot for SN ratios

Conclusion

In this study the effect of process parameters on the response variables (MRR, SR) of magnesium alloy (AZ31) was investigated. An effort is made to obtain the effect of input parameters such as Peak current, voltage, pulse on time, and pulse off time in Wire- EDM process. these parameters play a significant role on the response characteristics of machine such as MRR and SR. in the design of experiment taguchi method is used to evaluate the optimum input parameters combination for the maximum MRR and minimum SR. The most significant parameter in the Surface roughness was pulse off time followed by the voltage. The most significant parameter in the material removal rate is pulse on time followed by voltage.

6.References:

[1] Norliana Mohd Abbas, Darius G. Solomon, Md. Fuad Bahari (2007).“A review on current research trends in electrical discharge machining (EDM)” Journal of Mechanical Science and Technology

[2] Subramanian Gopalakannan and Thiagarajan Senthilvelan(2007) “Optimization of machining parameters for EDM operations based on central composite design and desirability approach” International Journal of Machine Tools & Manufacture 47

[3] Chinmaya P Mohanty, Siba Shankar Mahapatra, Manas Ranjan Singh (2014), “An Experimental Investigation of Machinability of Inconel 718 in Electrical Discharge Machining” , Procedia Materials Science 6 (2014) 605 – 611

[4] R. Kumar, I. Singh, D. Kumar (2013), “Electro Discharge Drilling of Hybrid MM”Procedia Engineering 64 1337 – 1343

[5] C. Blawert, N. Hort and K.U. Kainer (2004), “AUTOMOTIVE APPLICATIONS OF MAGNESIUM AND ITS ALLOYS” Trans. Indian Inst. Met. Vol.57, No. 4, pp. 397-408

[6] M.A. Razaka,c, A.M. Abdul-Rania,T.V.V.L.N. Raoa, S.R. Pedapatia, S. Kamalb(2016), “ Electrical Discharge Machining on Biodegradable AZ31