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An estimating the effect of control process variables on kerf width in wire EDM of AZ91 magnesium alloy by Taguchi method

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Abstract. The target of the current research study is to contemplate the impacts of diversecontrol parameters in WEDM, for example, wire tension, wire speed, discharge duration on and Pulse off time over kerf width (KW) and to get the ideal arrangements of process parameters. The trial work comprises of machining of Magnesium AZ91 alloy material utilizing Wire EDM (WEDM).The wire (tool) material was brass wire by means of zinc coated. The observations of the cutting process are based on L27 Taguchi's array for optimizing the control variables for these composite. The criticalness of each cutting parameters are associated to the most impacting factors which influences the procedure reactions. The ideal cutting variables are selected from the outcomes. Minitab V.18 software are developed for establishing good relationship between machining variables, such as wire feed, pulse duration time , wire tension & pulse off duration with the cutting control process criteria kerf width.

Key words: Wire EDM, Taguchi, AZ91 alloy, kerf width & Optimization

1. Introduction:

Wire EDM has all the earmarks of being exceptionally encouraging strategy among all non-conventional machining strategies [1-4]. The industrial growing sectors utilizing Wire EDM technology comes under five main different categories: tool and die, power generation, aerospace, automotive, oil and gas industries. WEDM maintains the largest percentage of share, as much as 50% and ECM about 15% lagging behind laser processes which are 20%. In many application areas which offers several benefits that include better precision, higher cutting rate & controlled material removal and also different types of materials that can be processed. The main aim of Wire EDM users & manufactures is to obtain a better steadiness of the machining process and increased productivity. More colorful materials are produced, and more mind boggling shapes are introduced and regular machining activities achieve their restrictions; the expanded utilization of Wire EDM in assembling keeps on developing at a quickened rate. Wire EDM makers and client accentuate on accomplishment of higher machining profitability with a coveted exactness and surface wrap up. Magnesium composites are combinations of magnesium alloys with other metals, often aluminum, manganese, copper, zinc, silicon rare earths metals and zirconium [5-8]. Magnesium compounds have hexagonal cross section structure which influences the essential properties of this composite. That is why, alloys of magnesium are mostly used as cast alloys & wrought alloys which has been more extensive. Cast magnesium alloys are utilized for a little parts of present day auto parts, and magnesium square; incredible magnesium is likewise utilized for camera bodies and in focal points segments.

The overall material grades of magnesium is available, in the research work the grade used to do the research is identified to be AZ91, which had most application in aircraft industry [9]. The material magnesium AZ91 is selected for the process where these metals have good mechanical strength and are conductive [10-12]. This research work also aims at investigating the main effects of the different Wire EDM control parameters like as wire speed, wire feed, Pulse on and Pulse off time on KW by using the technique named Taguchi. MINITAB version18 software was used so as near optimize the operating variables of Wire EDM for magnesium AZ91.

2. Materials &Methods

2.1. Properties of AZ91 alloy

The mass production of lightweight metal castings for moderate strength applications requires the employ of high volume die-casting techniques. The predominant magnesium alloy used for both die along with sand casting is AZ91, containing approximately 9% aluminum and 1% zinc, which possess excellent casting properties and reasonable strength. The strength increase of AZ91 and other alloys with additions derives from the configuration of the MgnAl^ eutectic, which may be re-precipitated. The composition of AZ91 alloy is given in Table 1.

Table 1. Composition of AZ91

Al	Zn	Mn	Fe	Si	Cu	Zr	Mg
8.84	0.61	0.18	0.02	0.02	0.005	0.002	Balance

2.2. *Experimental design &process parameters*

Four electrical control process parameters like Pulse on time (A), Pulse off time (B), pulse current (C) and gapset voltage (D) and two nonelectrical control process variables wire tension (F) & finally the speed of wire drum (E) were selected to conduct experiment. This testing was planned using Taguchi's technique [13-15]. Finally, the trial was conducted relating to L27 design matrix. Pilot experiment was conducted for finalizing process parameters. The levels of different variables & their assignments are exhibited in the Table 2.

Table 2. Control variables levels.

Symbol	Process variables	Level -1	Level- 2	Level- 3
A	Pulse on time	106	116	126
B	Pulse off time	40	50	60
C	Pulse current	70	150	230
D	Gap Voltage	20	30	40
E	Wire speed	4	6	8
F	Wire tension	4	8	12

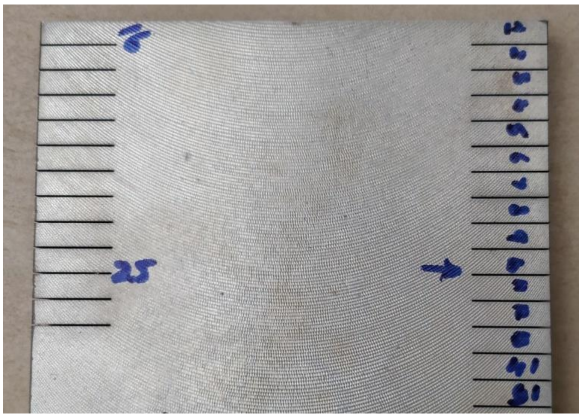

Figure 1. Kerf width for AZ91 magnesium alloy

2.3. Experimental Set Up

Electronica Sprint cut CNC WEDM was used for machining of AZ91 magnesium alloy. There are 27 experiments conducted by changing process parameters combination. Wire EDM is a start disintegration process. The flashes are produced between the work materialalong with the wire terminal. The material which is getting expelled by a progression of discrete sparkles occurring at the zone to be cut through electro-warm system. The machined small particles were passed away by the stream of dielectric liquid. The wire is held by a stick direct at top and lower parts of work piece. The work specimen was seized to 100 x 100 x 10 mm rectangular plate and 0.25 mm diameter of zinc-coated wire was employed as a part of this investigation. Deionized water was utilized as dielectric liquid at room temperature. In the wake of machining, the examples were cleaned with acid after machining. Figure 1 shows the kerf width for AZ91 magnesium alloy.

Table 3. TaguchiL27 array.

Exp. No.	Pon	Poff	Current	Servo voltage	Wire feed	Wire tension
1	106	40	70	20	4	4
2	106	40	150	30	6	8
3	106	40	230	40	8	12
4	106	50	70	30	6	12
5	106	50	150	40	8	4
6	106	50	230	20	4	8
7	106	60	70	40	8	8
8	106	60	150	20	4	12
9	106	60	230	30	6	4
10	116	40	70	30	8	8
11	116	40	150	40	4	12
12	116	40	230	20	6	4
13	116	50	70	40	4	4
14	116	50	150	20	6	8
15	116	50	230	30	8	12
16	116	60	70	20	6	12
17	116	60	150	30	8	4
18	116	60	230	40	4	8
19	126	40	70	40	6	12

Exp. No.	Pon	Poff	Current	Servo voltage	Wire feed	Wire tension
20	126	40	150	20	8	4
21	126	40	230	30	4	8
22	126	50	70	20	8	8
23	126	50	150	30	4	12
24	126	50	230	40	6	4
25	126	60	70	30	4	4
26	126	60	150	40	6	8
27	126	60	230	20	8	12

3. Results and Discussion

3.1. Analysis of experiment

S\N proportion is employed to gauge the affectability of the reaction which to be explored at controlled way. The signal represents attractive effect for the response and noise represents the unwanted effect for the responses. Lower the best (HB) is selected to KW. The S/N ratio expression for KW is as follows [16]:

Smaller to be the better $\left(\frac{S}{N}\right)SB = -10log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y^2}\right]$ (1)

Larger to be the better $\left(\frac{S}{N}\right)SB = -10log\left[\frac{1}{n}\sum_{i=1}^{n}y^2\right]$ (2)

Nominal to be the better $\left(\frac{S}{N}\right)SB = -10log\left[\frac{1}{ns}\sum_{i=1}^{n}y^2\right]$ (3)

where

Y_i= i^{th} value of response measured

N = Maximum number of runs

S = standard deviation

3.2 Process control variables effect on kerf width

Average kerf width values are provided in the Table 4 for AZ91 magnesium alloy. The analysis gave the special belongings of six main process variables while processing the magnesium alloy. Based on at 95% assurance level (x=0.05), Pulse on duration, Pulse off duration, current & gap voltage were known to have noteworthy effect towards kerf thickness whereas speed of wire drum along with wire tension did not have significant effect [17]. The involvement of each process variables is calculated by ANOVA. The pulse on duration was the nearly all noteworthy factor which contributed maximum of 68.40% to the kerf width.

The contribution from further variables were reach your peak current 5.8%, gap voltage 7%, pulse off duration 5.8%. The average S/N ratios and average mean values for kerf thickness of every one parameter are made known in Tables 5 and 6. The performance of each control factors at unlike levels from the S/N fraction analysis, the best levels for minimum kerf thickness are A1, B1, C1, D1, E3 & F3. Figure 3 & 4 gives the main effect & interaction effect of control variables over kerf width. Most favorable value of kerf width is predicted as 0.316 mm using Minitab version18 statistical software.

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3.3. Pulse on time effect on kerf width

The cause of pulse on moment in time on the kerf thickness was observed from figure 2. kerf width which increases owed to enhance in pulse on duration increases. The pulse on moment is the first most significant influencing parameter on top of kerf width [19]. High temperature is observed at high strength discharge energy when the spark strikes the surface, Due to this effect part of sample to melt and evaporated. Due this effect, a large magnitude of material melts and removed. These consequences are in line with a few of the researchers [20, 21].

3.4. Pulse off time Effect on kerf width

The impact of pulse off interval on the cutting speed is made known in Fig 2.Increased pulse off point in time duration reduces KW. Kerf increases initially then it decreases for pulse of time 60 machine units. This is due to less quantity of discharges occur for a specific period of time. Thus, small quantity of metal melting takes place for larger pulse off time. This produces lower KW. The results from this investigation are in agreement with other researchers [22, 23].

Table 4. Kerf width & S/N ratio.

Exp. No.	Pon	Poff	Current	Servo voltage	Wire feed	Wire tension	Kerf width	S/N ratio of kw
1	106	40	70	20	4	4	0.323	9.807
2	106	40	150	30	6	8	0.326	9.727
3	106	40	230	40	8	12	0.332	9.577
4	106	50	70	30	6	12	0.336	9.465
5	106	50	150	40	8	4	0.332	9.569
6	106	50	230	20	4	8	0.333	9.542
7	106	60	70	40	8	8	0.335	9.499
8	106	60	150	20	4	12	0.326	9.736
9	106	60	230	30	6	4	0.347	9.185
10	116	40	70	30	8	8	0.346	9.210
11	116	40	150	40	4	12	0.347	9.193
12	116	40	230	20	6	4	0.358	8.914
13	116	50	70	40	4	4	0.367	8.707
14	116	50	150	20	6	8	0.357	8.947
15	116	50	230	30	8	12	0.361	8.850
16	116	60	70	20	6	12	0.343	9.303
17	116	60	150	30	8	4	0.348	9.177
18	116	60	230	40	4	8	0.357	8.955
19	126	40	70	40	6	12	0.352	9.061
20	126	40	150	20	8	4	0.348	9.177
21	126	40	230	30	4	8	0.357	8.955
22	126	50	70	20	8	8	0.344	9.269
23	126	50	150	30	4	12	0.359	8.890
24	126	50	230	40	6	4	0.364	8.770
25	126	60	70	30	4	4	0.357	8.947
26	126	60	150	40	6	8	0.358	8.914
27	126	60	230	20	8	12	0.348	9.168

3.5. Discharge current effect on kerf width

Figure 2 indicates the effect of pulse current on the cutting speed. Pulse current is the second most significant process parameter affecting the kerf width. The kerf increases as the pulse current increases. Discharge energy becomes intense with an increase in the pulse current, due to this higher kerf width produced. Hence to obtain lower kerf width, the pulse current should be kept low. These results are in agreement with other researchers [24].

3.6. Gap voltage effect on kerf width

Figure 2 demonstrates the impact of current on the kerf width. Kerf increases with increase in gap voltage. The influence of gap voltage on kerf width is significant parameter. Hence to obtain lower kerf, the gap voltage should be kept low. These outcomes are in concurrence with different analysts [25, 26].

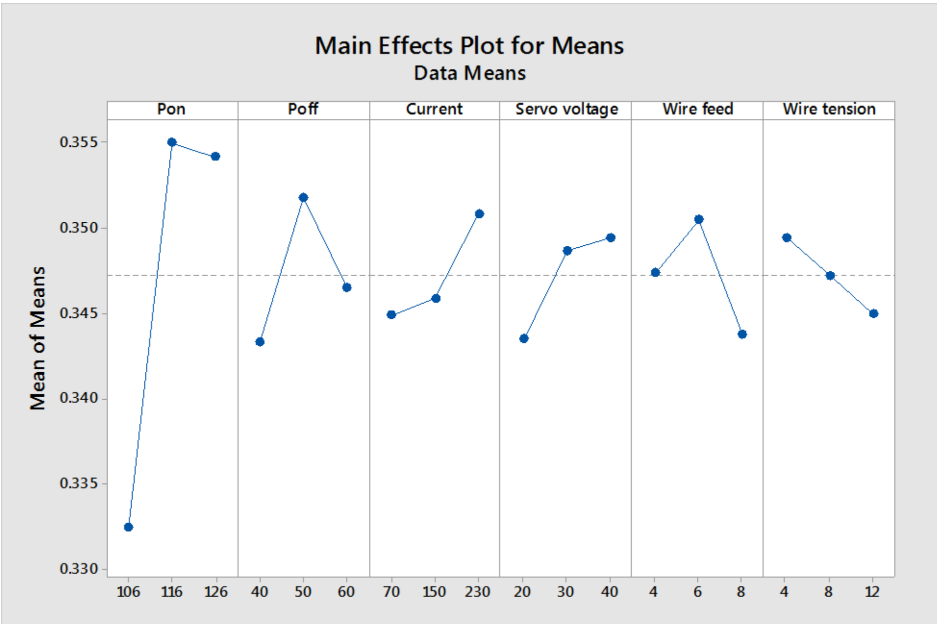

Figure 2. Kerf width main effects plot.

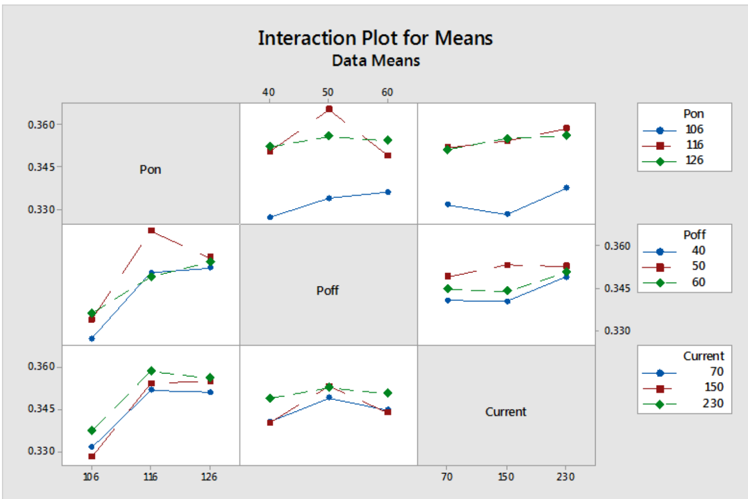

Figure 3. Kerf width interaction plots for means.

Table 5. Analysis of variance for kerf width.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pon	2	0.002779	0.00139	62.8	0
Poff	2	0.000233	0.000117	5.27	0.02
Current	2	0.000223	0.000112	5.04	0.022
Servo voltage	2	0.00028	0.00014	6.32	0.011
Wire feed	2	0.000138	0.000069	3.12	0.076
Wire tension	2	0.0001	0.00005	2.25	0.142
Error	14	0.00031	0.000022		
Total	26	0.004063			

4. Conclusions

AZ91 magnesium alloy was machined on wire EDM using zinc covered brass wire. The trial was conducted relating to Taguchi's L27 orthogonal array. The estimation of finest machining variables to minimize KW was investigated using Taguchi's practice was studied. The conclusion pinched from this study are as follows:

1. The linear parameters Pulse on time, Pulse off time, current along with gap voltage had noteworthy effect on kerf width. Wire feed along with wire tension did not have noteworthy effect on kerf thickness.

2. The Pulse on time was the most noteworthy variable contributing to the kerf width (68.5%), followed by pulse off time (5.7%) along with gapset voltage (6.8%). The contribution by peak current was 5.7%. Wire feed & wire tension contribution was less than 3 %.

3. The optimum rate of course variables for the forecasted optimum rate of KW (0.316 mm) is pulse on time 106 units (Level 1), Pulse off time 40 units (Level 1), peak current 70 units (Level 1), gap voltage 20 units (Level 1), wire feed 8 units (Level 3) along with wire tension 12 units (Level 3).

4. The optimum results are adopted in validation study & the results based on WEDM process responses can be efficiently improved.

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