VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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OPTIMIZATION OF KERF WIDTH OBTAINED IN WEDM OF ALUMINUM HYBRID COMPOSITE USING TAGUCHI METHOD

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ABSTRACT

In this paper, an experiment is conducted to optimize the kerf width of wire electrical discharge machining (WEDM) on Aluminum hybrid composite with Zinc coated brass wire using Taguchi method. Aluminum metal matrix composites (MMCs) reinforced with silicon carbide particulate (SiCp) find several applications due to their improved mechanical properties for a wide variety of aerospace and automotive applications. The hybrid composite (Al6061/SiC/Graphite) is prepared by stir casting route. Parameters considered for this study is pulse on time, pulse off time ,peak current, gap set voltage, wire feed and wire tension. Taguchi orthogonal method is used to design the experiment (L27). In this analysis of results shows that kerf width is mostly influenced by the peak current.

Keywords: WEDM, Taguchi method, hybrid composite, kerf width.

INTRODUCTION

Metal matrix composites find applications in aero space industry and automobile applications due to their light weight, high specific strength and good wear resistant. Wear strength of composites are improved by adding solid lubricants like graphite, mos_2 etc. Addition SiC to aluminium increases the harness of composite. Reinforcement is usually non-metallic and commonly ceramic such as SiC and Al_2O_3 (Surappa *et al*., 2003). Electrical discharge machining is one of the non traditional machining processes which have been widely used to produce complicate shapes, dies and moulds. It is also used for finishing parts for aero space and automotive industry (Snoes *et al*., 1986). The machining of PAMCs presents a significant challenge, since a number of reinforcement materials are significantly harder than the commonly used high-speed steel (HSS) and carbide tools (Clyne, 1992; Miracle *et al*., 2005) Wire electrical discharge machining is an important and promising non conventional machining process, which can be used to machine the electrically conductive work materials irrespective of their strength and hardness.

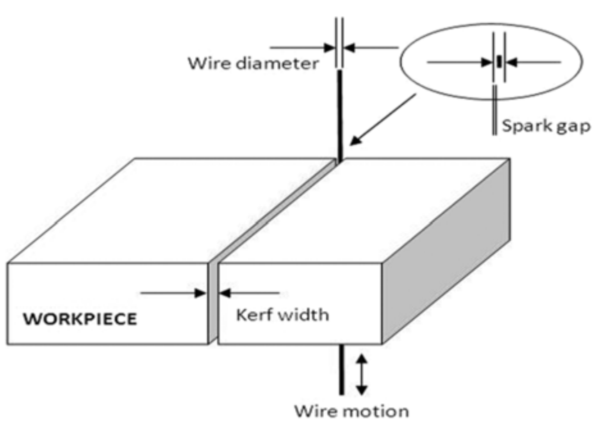

Figure-1. Details of kerf width in WEDM (Scott *et al*. (1991)).

During machining in WEDM, no force is applied on work piece during machining in WEDM because there is no direct contact between tool and work. The most important performance measures in WEDM are material removal rate, surface roughness, kerf width and wire wear rate. The kerf determines the dimensional accuracy of the finished products. The kerf width is calculated by summing up the wire diameter to 2 x wire work piece gap distance. The wire work piece gap ranges from 0.025 to 0.075 mm.

LITERATURE SURVEY

Mahapatra *et al*. (2006) studied on parametric optimization of WEDM process on D2 tool steel using L_{27} orthogonal array (OA) Taguchi method. The results of analysis of variance (ANOVA) showed that discharge current, pulse duration and discharge flow rate are the significant factors for maximizing the MRR and surface finish (SF). Genetic algorithm (GA) was used to obtain the optimum machining parameters for multi-objective outputs using several combinations of the weight. The study concluded that optimal machining performance with maximization of MRR and SF occurs under equal importance of weighting factors.

Datta *et al*. (2010) studied the process behaviour of WEDM with process parameters on MRR, SF and kerf width for D2 tool steel using Taguchi L_{27} OA. GRA was also adopted to convert the multi-objective criteria into an equivalent single-objective function. Optimal setting was verified and it showed good agreement with practical values through confirmatory tests.

Yan *et al.* [2005] examined the effect of WEDM machining parameter discharge duration on kerf (width of slit) while machining 10 and 20 vol % Al_2O_3/6061 Al composite. The experimental results revealed that the width of slit increased with increasing the discharge duration. The wire electrode wear rate (EWR) increases with increase in the percentage of reinforcing Al_2O_3 particles (0, 10, and 20 vol % of Al_2O_3/6061 Al). Also, it increased gradually as the discharge duration increased.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

The effects of process parameters including wire tension, flushing rate and wire speed of WEDM on wire breakage were investigated. A very low wire tension, a high flushing rate and a high wire speed are required to prevent wire breakage.

Chiang *et al*. (2006) presented an approach for optimization the WEDM process of Al_2O_3 particle reinforced material (6061) with multiple performance characteristics based on the grey relational analysis and Taguchi technique. In their study, the machining parameters, cutting radius of work piece, on time, off-time of discharging, arc on-time, arc off-time of discharging voltage, wire feed and water flow are optimized with consideration of multiple performance such as MRR and SR.

Muthu Kumar V *et al*. (2010) demonstrates optimization of Wire Electrical Discharge Machining process parameters of Incoloy800 super alloy with multiple performance characteristics such as Material Removal Rate (MRR), surface roughness and Kerf based on the Grey - Taguchi Method. The process parameters considered in this research work are Gap Voltage, Pulse On-time, Pulse Off-time and Wire Feed. Taguchi's L9 Orthogonal Array was used to conduct experiments. Optimal levels of process parameters were identified using Grey Relational Analysis and the relatively significant parameters were determined by Analysis of Variance.

Tosun *et al.* (2004) investigated the effect and optimization of machining parameters on the kerf (cutting width) and material removal rate (MRR) in wire electrical discharge machining (WEDM) operations. Based on ANOVA method, the highly effective parameters on both the kerf and the MRR were found as open circuit voltage and pulse duration, whereas wire speed and dielectric flushing pressure were less effective factors. The results showed that open circuit voltage was about three times more important than the pulse duration for controlling the kerf, whereas open circuit voltage for controlling the MRR was about six times more important than pulse duration.

MATERIALS AND METHOD

PREPARATION OF HYBRID COMPOSITE

In this study, the hybrid MMC has been fabricated by stir casting process. The hybrid composite consists of 10 wt% SIC and 5 wt% Graphite particulates in metal matrix Al6061 alloy. The Al alloy of 6061 series is having great potential to be utilized in aerospace and automotive industries because of its high strength-to-weight ratio and good resistance to corrosion. The weight % composition of Al6061 alloy is shown in Table-1. Reinforcements SiC and graphite in particulate form are used to fabricate the hybrid composite. The weight % composition of SiC and graphite are shown in Table-2. These reinforcements have 10-13 micron size particles of SiC & graphite.

Table-1. Composition of Al6061 alloy.

Mg	Si	Fe	Cu	Cr	Al
1.1	0.64	0.48	0.33	0.04	Remaining

MACHINING PARAMETERS AND RESPONSE

Six input process parameters in WEDM, namely, pulse on time, pulse off time, pulse current, gap set voltage, the wire drum speed and wire tension were chosen to study their effects on SR and kerf width while machining the hybrid composite. The ranges of these process parameters were selected on the basis of the pilot experiments. The levels of various parameters and their designations are presented in Table-2.

Table-2. Process parameters and their levels.

Symbol	Process parameter	Level 1	Level 2	Level 3
A	**Pulse on time**	**108**	**117**	**126**
B	Pulse off time	40	50	60
C	Pulse current	90	160	230
D	Gap set Voltage	10	30	50
E	Wire drum speed	3	4	5
F	Wire tension	4	8	12

EXPERIMENTAL DESIGN USING TAGUCHI METHOD

Taguchi technique is an efficient tool for the design of a high-quality manufacturing system. It is a method based on OA experiments, which provide much reduced variance for the experiment with optimum setting of process control parameters. The six control parameters, that is, pulse on time (A), pulse off time (B), peak current (C),Gap set voltage (D), wire drum speed (E) and wire tension(F) at three levels were selected in this study. The experiments were done according to Table-3. This table only represents particular level of the various factors of the process at which the experiments would be conducted. Kerf width should be as minimum as possible in the WEDM process. Kerf width is an important feature of the laser cutting process that provides the advantage of this technology compared to other methods of contour cutting

Taguchi method, pioneered by Dr. Genichi Taguchi, greatly improves engineering productivity. Taguchi's method for improving the quality of a product through

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minimizing the effect of variation without eliminating the causes. The S/n ratio can be defined as nominal - the- best, smaller - the -better or larger - the- better according to the characteristics of the problem. In this work smaller - the - better is considered for the kerf width calculation.

S/N ratio for smaller – the – better

$$\frac{S}{N_{(Smaller)}} = -10 \log\left(\frac{\sum y_i^2}{n}\right)$$

Table-3. Design Matrix for L27 orthogonal array.

Experimental run	Control factors and levels					
	A	B	C	D	E	F
1	1	1	1	1	1	1
2	1	1	1	1	2	2
3	1	1	1	1	3	3
4	1	2	2	2	1	1
5	1	2	2	2	2	2
6	1	2	2	2	3	3
7	1	3	3	3	1	1
8	1	3	3	3	2	2
9	1	3	3	3	3	3
10	2	1	2	3	1	2
11	2	1	2	3	2	3
12	2	1	2	3	3	1
13	2	2	3	1	1	2
14	2	2	3	1	2	3
15	2	2	3	1	3	1
16	2	3	1	2	1	2
17	2	3	1	2	2	3
18	2	3	1	2	3	1
19	3	1	3	2	1	3
20	3	1	3	2	2	1
21	3	1	3	2	3	2
22	3	2	1	3	1	3
23	3	2	1	3	2	1
24	3	2	1	3	3	2
25	3	3	2	1	1	3
26	3	3	2	1	2	1
27	3	3	2	1	3	2

EXPERIMENTAL SET UP

Experiments were conducted on Electronica Sprint cut (Electra-Elplus 40A Dlx) CNC wire electrical discharge machine to study the surface roughness and kerf width affected by the machining parameters at different levels. WEDM is a spark erosion process. The sparks are generated between the work piece and the wire electrode. The dielectric fluid is continuously fed into the machining zone with required pressure. The material is getting removed by a series of discrete sparks taking place at the area to be machined through electro-thermal mechanism. Experimental set up of the wire electrical discharge machine is shown in Figure-2.

During machining process small gap maintained between the work and wire material. The machined particles were flushed away by the continuous flow of the dielectric fluid. The wire is held by a pin guide at the upper and lower parts of the work piece. The work specimen size used in this study is 95 x 80 x 8 mm rectangular plate. Zinc coated brass electrode wire of 0.25

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mm diameter was used in this study. Deionised water was used as dielectric fluid at room temperature. After machining, the specimens were cleaned with acetone. The kerf was measured using video measuring system. The kerf values were measured at three places spread over the entire length of cut. The kerf values used in this study are the mathematical average of three measurements made from the specimen in each cut.

Figure-2. WEDM experimental set up (Electronica sprint cut).

RESULT AND DISCUSSIONS

The results obtained are analysed using S/N ratios, response table and response graphs with the help of Minitab software. Table-4 shows the kerf width values and its corresponding S/N ratio values. Figure-4 shows main effects plots for kef width. Pulse on time is most influenced factor for kerf width. Peak current, gap set voltage and wire feed are not significant factors. The response table 5 shows contribution of different process parameters. Pulse on time was the most significant parameter that contributed maximum (48.25%) to the kerf width followed by pulse off time (14.45%), wire tension (7.3%) and peak current (1.89%). Table 6 shows the ANOVA for kerf width. The S/N analysis suggests that the best levels for minimum value of kerf width are A1B1C2D3E3F3.

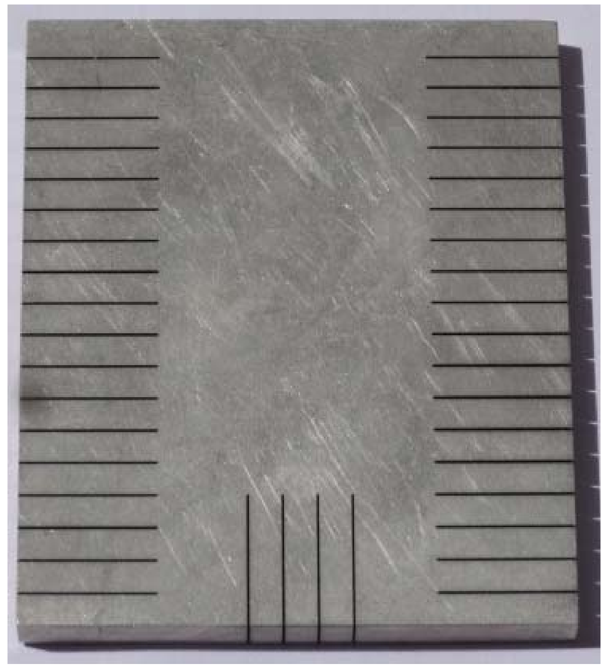

Figure-3. Kerf width of machined work piece.

VOL. 12, NO. 2, JANUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-4. Kerf width and S/N ratio.

Ex. number	Pulse on time	Pulse off time	Pulse current	Gapset voltage	Wire drum speed	Wire tension	kerf width (μm)	S/N ratio
1	108	40	90	10	3	4	300	-49.54242509
2	108	40	90	10	4	8	300	-49.54242509
3	108	40	90	10	5	12	292	-49.30765703
4	108	50	160	30	3	4	304	-49.65747167
5	108	50	160	30	4	8	300	-49.54242509
6	108	50	160	30	5	12	301	-49.57132991
7	108	60	230	50	3	4	297	-49.45512899
8	108	60	230	50	4	8	303	-49.62885257
9	108	60	230	50	5	12	302	-49.60013886
10	117	40	160	50	3	8	303	-49.62885257
11	117	40	160	50	4	12	309	-49.79916959
12	117	40	160	50	5	4	314	-49.93859296
13	117	50	230	10	3	8	317	-50.02118524
14	117	50	230	10	4	12	313	-49.91088675
15	117	50	230	10	5	4	322	-50.15711743
16	117	60	90	30	3	8	327	-50.23766722
17	117	60	90	30	4	12	304	-49.65747167
18	117	60	90	30	5	4	317	-50.02118524
19	126	40	230	30	3	12	302	-49.60013886
20	126	40	230	30	4	4	317	-50.02118524
21	126	40	230	30	5	8	302	-49.60013886
22	126	50	80	50	3	12	310	-49.82723388
23	126	50	90	50	4	4	327	-50.29095505
24	126	50	90	50	5	8	322	-50.15711743
25	126	60	160	10	3	12	316	-49.99374165
26	126	60	160	10	4	4	304	-49.65747167
27	126	60	160	10	5	8	318	-50.0485424

Table-5. Response table for signal to noise ratios for kerf width smaller is better.

Level	Pulse on Time	Pulse off time	Peak current	Gap set voltage	Wire feed	Wire tension
1	-445.848	-446.981	-448.584	-448.181	-447.964	-448.742
2	-449.372	-449.136	-447.838	-447.909	-398.393	-448.407
3	-449.197	-448.3	-447.995	-448.326	-448.402	-447.268
Delta	3.524	2.155	0.746	0.417	0.437975	1.473765
Rank	1	2	4	6	5	3

 ISSN 1819-6608

Table-6. Response table for r kerf width (Raw data).

Level	Pulse on Time	Pulse off time	Peak current	Gap set voltage	Wire feed	Wire Tension
1	**299.89**	**304.33**	**311**	**309.11**	**308.44**	**311.33**
2	314	312.89	307.67	308.22	308.56	310.22
3	313.11	309.78	308.33	309.67	310.22	305.44
Delta	14.11	8.45	3.33	1.45	1.66	5.89
Rank	1	2	4	6	5	3

Table-7. ANOVA table for kerf width (S/N ratio).

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution
Pulse on time	**2**	**0.87648**	**0.87648**	**0.43824**	**12.55**	**0.001**	**48.25%**
Pulse off Time	2	0.26237	0.26237	0.13119	3.76	0.049	14.45%
Peak current	2	0.03442	0.03442	0.01721	0.49	0.621	1.89%
Gap set voltage	2	0.00996	0.00996	0.00498	0.14	0.868	0.05%
Wire feed	2	0.01195	0.01195	0.00597	0.17	0.845	0.06%
Wire tension	2	0.13267	0.13267	0.06633	1.90	0.186	7.3%
Error	14	0.48890	0.48890	0.03492			26.91%
Total	26	1.81675					100

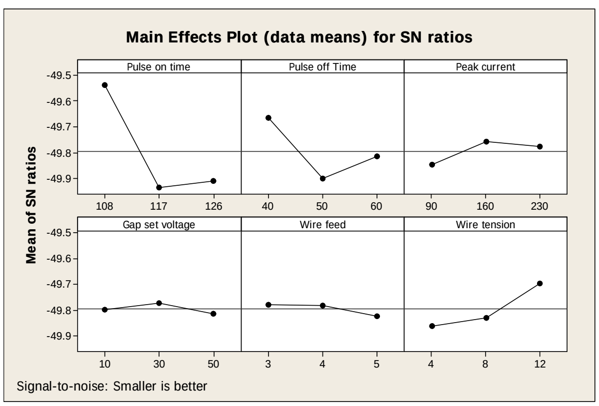

Figure-4. Effect of control parameters on kerf width.

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