

Experimental investigation of WEDM process parameters for cutting speed using response surface methodology

A Muniappan*, G Md Shaqib ,V Jayakumar, G Bharathi Raja & R Soloman

Department of Mechanical Engineering, Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India

*Corresponding Author : Inspire.munish@gmail.com

Abstract. In this present experimental study, the effect and advancement of machining parameters on cutting speed (CS) in wire electrical discharge machining (WEDM) operations were studied. The hybrid metal matrix composite (MMC) was manufactured by process named as stir casting utilizing particulates of Silicon carbide and graphite each in Al6061 combination. The analyses were outlined with response surface methodology. WEDM parameters resemble Pulse on time, current, Pulse off time and control speed are considered. The optimized parameters are Pulse on time (Level 3), Pulse off time (Level 1), peak current (Level 2) and control speed (Level 2) are the best combination to achieve best material removal rate. Pulse off time, control speed, Pulse on time and discharge current have considerable effect and most influenced control parameters on CS.

Keywords: WEDM; RSM; stir casting, hybrid composite & cutting speed.

1. Introduction

Running with the progression of the mechanical era, the solicitations for composite materials having high hardness, quality, wear assurance, and disintegration security are growing [1]. Research had been done in MMC composites more than a significant extended period of time, by examiners on creation methodologies and material property estimations, and various sublime research happens have been gained [2-4]. Metal matrix composites discover applications in air space industry and auto applications in perspective of their light weight, high particular quality and uncommon wear safe. Electrical discharge machining is one of the non-conventional machining outlines which have been completely used to pass on intricate shapes, bombs hopelessly and shapes [5]. It is additionally utilized for completing parts for aerospace and automobile industry [6]. The machining of PAMCs presents a vital test, since various help materials are essentially harder than the routinely utilized snappy steel and carbide instruments [7-8]. Wire electrical machining is an essential nonconventional machining process which can be utilized to machine the electrically conductive work materials. In the midst of machining in WEDM, no power is associated on sample work piece in the midst of machining in WEDM in light of the way that there is no prompt contact among gadget and work. The most key execution measures in WEDM are material ejection rate, surface finish, kerf and wire wear rate. The present work aims at applying Taguchi method for optimization of cutting speed machined by WEDM process of Al/SiC/Gr hybrid composite.



2. Literature Survey

The true motivation behind this writing survey is to give foundation data on the issues to be considered in this postulation and to mention the present investigation. The utilization of aluminum composite is unavoidable in aviation and vehicle ventures attributable to its properties of high quality to weight proportion, excellent erosion protection, simple machinability and ease [9]. Be that as it may, issues related with aluminum and its compound material is poor high temperature execution and low wear protection. To overcome this issues, new designing materials have been created by fortifying hard support material on delicate aluminum grid is called aluminum metal matrix composites [10]. Shyam Lal and Sudhir Kumar [11-12] fabricated Al7075/Al₂O₃/SiC hybrid composite & studied the effect of WEDM parameters SR and kef width using Taguchi-Grey relational analysis. It was confirmed from results that roughness increased due to Pulse on time and current because of longer spark with high intensity, higher material melts per spark on the surface. Bikash [13] experimented result of WEDM parameters on MRR for gadget steel D2. They take wire reinforce speed, beat on-time, beat off-time, dielectric weight, open voltage, servo voltage and wire weight as information parameter. Adeel Ikram [14] selected the machining parameters (tallying discharge current, beat length, beat between time, administered beat time, most distant point effect, dielectric and material) on surface brutality and they concluded that a short pulse term combined close to a high apex regard gives better surface quality. Mahapatra et al. [15] used Taguchi method close to the extortion neural framework to refresh the precision, surface seriousness and MRR. They found that for the more than three responses, current is the most goliath factor. Ugrasen [16] investigated machining parameters for tool steel in WEDM. They found the range perfect setting of different parameters as pulse on time = 108-128 μ s, beat off time = 47-63 μ s, peak stream = 11-13 A, begin opening set voltage = 18-68 V, wire strain = 2-8 gm and water weight = 8-14 kg/cm². Sudhakara [17] found the perfect machining condition for dimensional deviation and SR for K460 instrument steel by wire EDM machine. They concluded that both current and alter disengage are very significant factors for estimation while peak current impacts the surface unpalatability.

3. Materials and Methods

3.1 Hybrid composite fabrication

Stir casting route was used for fabrication of Aluminum 6061 hybrid MMC [18]. The crossover composite comprises of 10% of silicon carbide and 5% of Graphite particulates in metal Al6061 alloy. These fortifications have 10-13 microns measure particles of SiC and 20-25 microns measure particles of graphite. Figure1 shows the stir casting melt setup used for casting of Al6061 hybrid composite.



Figure 1. Experimental setup for making stir cast.

3.2 Experimental design & Control variables

Four electrical control process parameters like Pulse on time (A), Pulse off time (B), pulse current (C) and control speed (D) were selected to conduct experiment. This experiment was designed using Response surface methodology [19-20]. Finally, the experiment was conducted according to L27 Box Benhon design matrix. Pilot experiment was conducted for finalizing process parameters. The levels of different parameters and their assignments are exhibited in Table 1.

Table 1. Control variables & its levels.

Symbol	Process parameter	Low	High
A	Pulse on time	108	124
B	Pulse off time	45	55
C	Current	100	220
D	Control speed	40	60

3.3 Experimental Set Up

Electronica Sprint cut CNC WEDM was used for machining of Al6061 MMC hybrid composite. There are 27 experiments conducted by changing process parameters combination. WEDM is a start disintegration process. The flashes are produced between the work material and the wire terminal. The material is getting expelled by a progression of discrete sparkles occurring at the zone to be machined through electro-warm system. The machined small particles were carried away by the persistent stream of the dielectric liquid. The wire is held by a stick direct at top and lower parts of work piece. Test set up of the wire electrical release machine is appeared in Figure 2. The work specimen was seized to 100 x 100 x 10 mm rectangular plate and 0.25 mm diameter of brass wire was utilized 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.

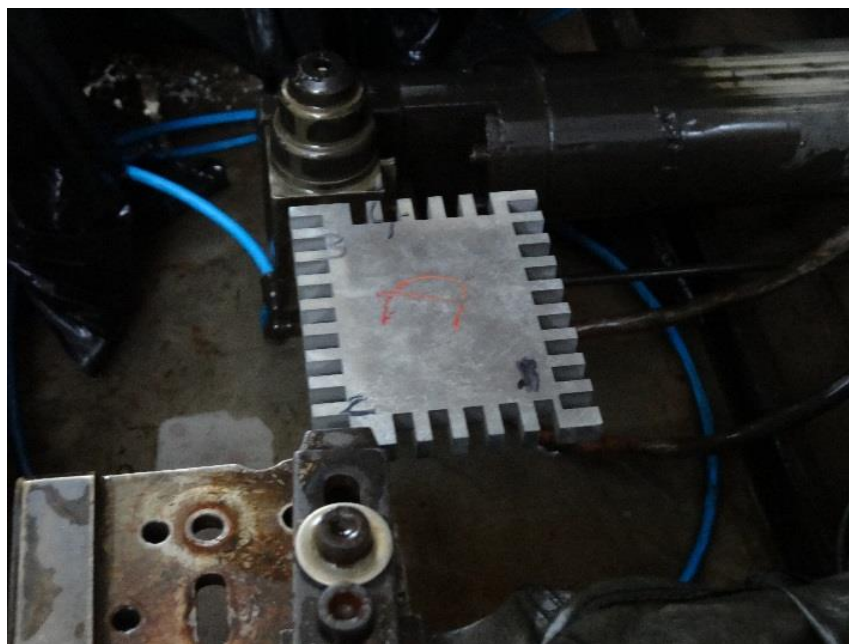


Figure 2. WEDM machined Work piece.

Table 2. Box Benhon Design matrix

Std	Order	Run Order	Pt Type	Blocks	Pulse on time	Pulse off time	Current	Control speed
16		1	2	1	116	55	220	50
14		2	2	1	116	55	100	50
17		3	2	1	108	50	100	50
15		4	2	1	116	45	220	50
22		5	2	1	116	55	160	40
6		6	2	1	116	50	220	40
8		7	2	1	116	50	220	60
12		8	2	1	124	50	160	60
1		9	2	1	108	45	160	50
13		10	2	1	116	45	100	50
20		11	2	1	124	50	220	50
19		12	2	1	108	50	220	50
24		13	2	1	116	55	160	60
27		14	0	1	116	50	160	50
3		15	2	1	108	55	160	50
26		16	0	1	116	50	160	50
18		17	2	1	124	50	100	50
2		18	2	1	124	45	160	50
21		19	2	1	116	45	160	40
5		20	2	1	116	50	100	40
25		21	0	1	116	50	160	50
9		22	2	1	108	50	160	40
4		23	2	1	124	55	160	50
23		24	2	1	116	45	160	60
7		25	2	1	116	50	100	60
10		26	2	1	124	50	160	40
11		27	2	1	108	50	160	60

4. Results and Discussion

4.1 Effect of process parameters on cutting speed

Table 3 shows the average cutting speed data. The analysis showed the effects of six main process parameters while cutting the hybrid aluminum composite. Based on at 95% confidence level ($\alpha=0.05$), Pulse on duration, Pulse off duration, current and control speed were found to have significant effect towards cutting speed whereas speed of wire drum and wire tension did not have significant effect. The performance of each parameter at different levels from the S/N ratio analysis, the best levels for maximum cutting speed are A_3 , B_1 , and C_2 & D_1 . The main effect plot for S/N ratio, mean are shown in Figure 3 and 4.

Table 3. Cutting speed.

Std Order	Run Order	Pt Type	Blocks	P _{on} time	P _{off} time	Current	Control speed	CS
16	1	2	1	116	55	220	50	4.87
14	2	2	1	116	55	100	50	4.98
17	3	2	1	108	50	100	50	6.5
15	4	2	1	116	45	220	50	5
22	5	2	1	116	55	160	40	4.02
6	6	2	1	116	50	220	40	3.97
8	7	2	1	116	50	220	60	5.98
12	8	2	1	124	50	160	60	6.2
1	9	2	1	108	45	160	50	6.72
13	10	2	1	116	45	100	50	5.02
20	11	2	1	124	50	220	50	4.97
19	12	2	1	108	50	220	50	6.7
24	13	2	1	116	55	160	60	5.87
27	14	0	1	116	50	160	50	5.01
3	15	2	1	108	55	160	50	6.89
26	16	0	1	116	50	160	50	5
18	17	2	1	124	50	100	50	4.97
2	18	2	1	124	45	160	50	4.99
21	19	2	1	116	45	160	40	3.97
5	20	2	1	116	50	100	40	4.01
25	21	0	1	116	50	160	50	4.97
9	22	2	1	108	50	160	40	6.4
4	23	2	1	124	55	160	50	4.98
23	24	2	1	116	45	160	60	5.95
7	25	2	1	116	50	100	60	6.01
10	26	2	1	124	50	160	40	3.69
11	27	2	1	108	50	160	60	7.01

4.2 Effect of Pulse on time on cutting speed

The effect of Pulse on time on the cutting speed was observed from figure 3. Cutting speed which increases due to increase in Pulse on duration increases. The Pulse on time is the third most significant influencing parameter on cutting speed. High temperature is observed at high intensity discharge energy when the spark strikes the surface. due to this effect part of specimen to melt and evaporated. Due this effect, a large quantity of material melts and removed. These results are in line with some of the researchers [21-22].

4.3 Effect of Pulse off time on cutting speed

The impact of Pulse off duration on the cutting speed is shown in Figure 3. Increased Pulse off time duration reduces cutting speed. This is due to less number 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 cutting speed. The results from this investigation are in agreement with other researchers [12, 23].

4.4 Effect of pulse current on cutting speed

Figure 3 indicates the effect of pulse current on the cutting speed. Pulse current is the second most significant process parameter affecting the cutting speed. The cutting speed increases as the pulse current increases. Discharge energy becomes intense with an increase in the pulse current, due to this better cutting speed achieved. Hence to obtain higher cutting speed, the pulse current should be kept high. These results are in agreement with other researchers [12, 23].

4.5 Effect of control speed on cutting speed

Figure 3 demonstrates the impact of current on the cutting velocity. Cutting speed decreases with increase in control speed. The influence of control speed on cutting speed is significant parameter. Hence to obtain higher cutting speed, the control should be kept low. These outcomes are in concurrence with different analysts [23].

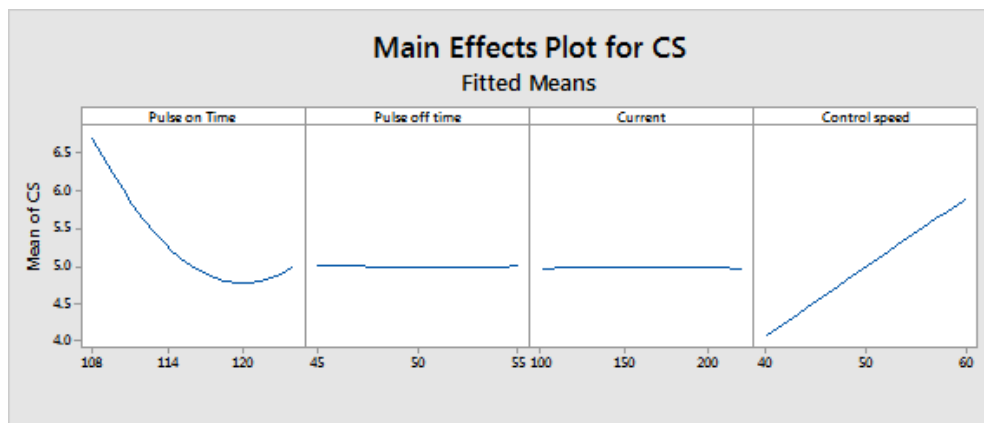


Figure 3. Cutting speed main effects plot for means.

Table 4. Analysis of variance for cutting speed.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	14	24.9183	1.7799	116.94	0.000
Linear	4	19.0583	4.7646	313.03	0.000
P _{on} Time	1	9.0480	9.0480	594.45	0.000
P _{off} time	1	0.0001	0.0001	0.01	0.927
Current	1	0.0000	0.0000	0.00	1.000
Control speed	1	10.0101	10.0101	657.66	0.000
Square	4	4.9331	1.2333	81.03	0.000
P _{on} Time*P _{on} Time	1	3.8798	3.8798	254.90	0.000
P _{off} time*P _{off} time	1	0.0003	0.0003	0.02	0.885
Current*Current	1	0.0039	0.0039	0.26	0.621
Control speed*Control speed	1	0.0011	0.0011	0.07	0.790
2-Way Interaction	6	0.9269	0.1545	10.15	0.000
P _{on} Time*P _{off} time	1	0.0081	0.0081	0.53	0.480

P _{on} Time*Current	1	0.0100	0.0100	0.66	0.433
P _{on} Time*Control speed	1	0.9025	0.9025	59.29	0.000
P _{off} time*Current	1	0.0020	0.0020	0.13	0.722
P _{off} time*Control speed	1	0.0042	0.0042	0.28	0.608
Current*Control speed	1	0.0000	0.0000	0.00	0.968
Error	12	0.1826	0.0152		
Lack-of-Fit	10	0.1818	0.0182	41.95	0.024
Pure Error	2	0.0009	0.0004		
Total	26	25.1009			

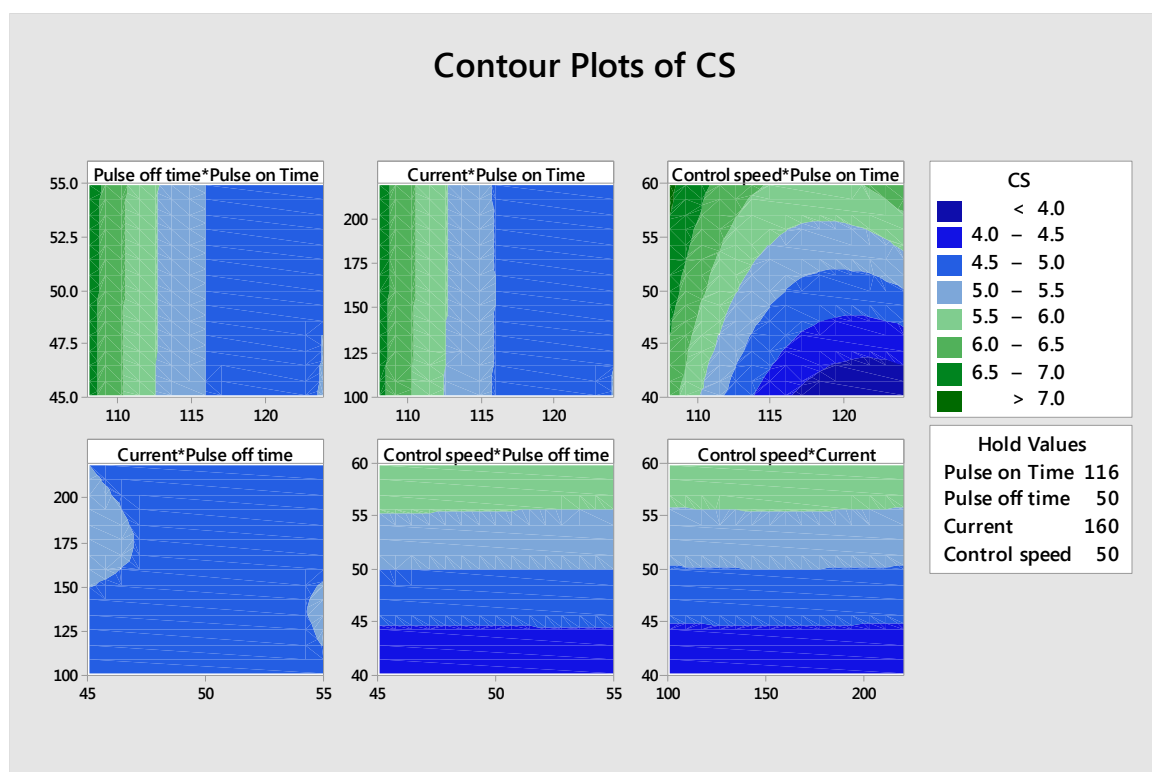


Figure 4. Contour plots for cutting speed.

4.6 Estimation of optimum performance characteristic

The optimum value of cutting speed is predicted at the selected level of parameters. The process parameter and their optimum levels are selected from the response graphs as $A_1B_2C_3$ and D_3 , that is Pulse on time (level 1), Pulse off time (level 2), Current (level 3) and control speed (level 3). The estimation of response can be computed as

$$\mu_{cs} = CS + (A_1 - CS) + (B_2 - CS) + (C_3 - CS) + (D_3 - CS) \quad \text{----- (1)}$$

where CS is the overall mean cutting speed (3.80 mm/min).

Optimum value of cutting speed is predicted as 7.185 mm/min using Minitab version 18 statistical software. The confirmation experiment was conducted with three trials for the optimum parameters. The average cutting speed observed from the experiment is 7.080 mm/min. there is

acceptable variation between predicted value and experimental value. Hence, Response surface methodology can be effectively used for optimization of WEDM process parameters.

5. Conclusions

Hybrid MMC of 15 wt% SiC (10%) and graphite (5%) particulates in Al6061 alloy was prepared using stir casting process. The cast hybrid composite was machined on wire electrical discharge machine. The estimation of optimum machining parameters to maximize cutting speed was investigated using Taguchi's technique was studied. The conclusions drawn from this study are as follows:

1. The linear parameters Pulse on time, Pulse off time, peak current and control speed had significant effect on cutting speed.
2. The Pulse off time was the most significant parameter contributing to the cutting speed (33.04%), followed by Pulse on time (26.25%) and control speed (21.91%). The contribution by peak current was 18.47%.
3. The optimum value of process parameters for the predicted optimum value of cutting speed (7.185 mm/min) is Pulse on time 126 units (Level 3), Pulse off time 40 units (Level 1), peak current 160 units (Level 2) and control speed 10 units (Level 1).
4. The optimum results are adopted in validation study and the results based on WEDM process responses can be effectively improved.

6. References

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