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AN EVALUATION OF MACHINABLITY Al 7029/10%SiC/ 2.5%B_4C METAL MATRIX COMPOSITE WITH ELECTRICAL DISCHARGE MACHINING

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ABSTRACT

In recent years, the modern metal industries need an efficient technique to produce dies and machining of hard materials like ceramics and high strength metal matrix composites, known as Electro Discharge Machining (EDM). It is a non- conventional electro-thermal machining process. In EDM some of the specifications such as huge number of parameters and inherent complexity of material removal technique built it even hard to choose machining conditions to attain optimal performance. A few industries known as aerospace, automobile and die making having great demand for Aluminium metal matrix because of its hard nature. In this work, a proper Design of Experiments (DOE) approach is taken to conduct the experiments using Taguchi to discover the impact of EDM processing parameters over surface finish and material removal rate (MRR) of AMMC. Finally observed that experiment No. 2 with pulse-on time, 10µs (A1); pulse-off, 8 µs (B2); current 10amps (C2) best surface finish amongst 16 experiments. This experimental study shows that the use of silicon carbide powder is found to be more suitable for improvement in surface characteristics. A result shows that pulse- on time is the dominating factor comparative to others factors which affect the surface characteristics.

KEYWORDS: Metal Matrix Composites; MRR, Optimization; EDM; Surface Roughness

INTRODUCTION OF EDM

Electro Discharge Machining (EDM) is defined as the process of metal removal with high precision rate by applying thermal energy generated by an electrical spark in order to erode the given work piece. It is an electro-thermal process where electrical energy is applied to produce electrical spark which comprises some thermal energy used for metal removal. This EDM is widely employed in die, mould and tool making industries to machine heat treated tool steel materials which are difficult-to cut materials and high strength temperature resistant alloys. It also can be employed for machining hard geometries at small batches or still on job-shop premise. The work piece material must be electrically conductive to apply machining by EDM.

Principle of EDM

It is the process of removing a portion of metal from the given work piece by frequently applying repeated spark discharge to produce erosion between the work piece and the tool. The electrical circuit, electrical set up and mechanical setup for EDM are shown. By using a servo system a narrow gap of about 0.025mm is kept between the work piece and the tool demonstrated in fig 1.1. In a dielectric fluid the work piece and the tool are immersed. Some of the most common dielectric liquids are Kerosene, EDM oil and deionized water and in some specific cases gaseous dielectrics are employed as well.

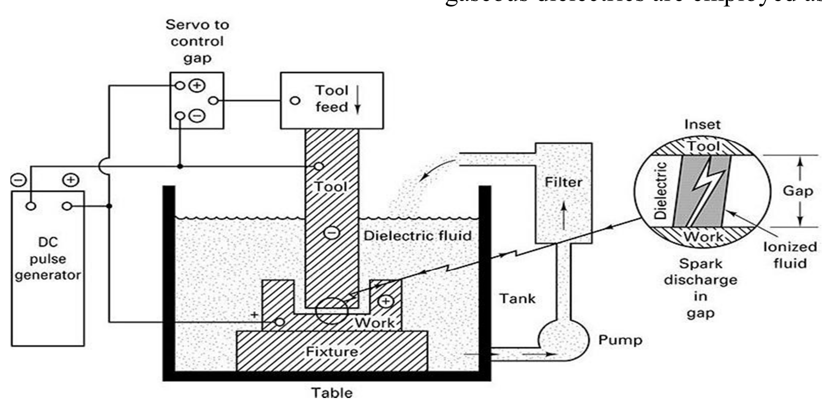

Figure 1: EDM working set up

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MATERIALS AND METHODS

Aluminium has one third density that of steel. Aluminium possess an excellent corrosion resistance because of its thin aluminum oxide layer which forms throughout its surface while it is uncovered to air. Aluminium / aluminum 7000 series consist of the alloying element zinc in a larger quantity. Aluminium / aluminum 7029 alloy is a heat treatable wrought alloy. The density of aluminum based hybrid MMCs is nearly one third that of steel, and offers high specific strength, stiffness, and high resistance to wear. The chemical properties of Aluminium 7029 are shown in table .1

Table 1: Chemical composition of Aluminium 7029

Material	ZINC	Magnesium	copper	silicon	Fe	Titanium	chromium
composition	4.5-5.2	0.14-0.4	0.5-0.9	0.4	0.12	0.12	0.04-0.35

Applications

Aluminium / aluminum 7029 alloy is chiefly used in the following areas: Automotive industry

Aviation industry

EXPERIMENTAL PROCEDURES

Workpiece Preparation

Crucible casting is used for the preparation of the hybrid aluminum metal matrix composite work material. Silicon carbide and Boron Carbide of average particle size 220 mesh and 140 mesh size respectively are used as the reinforcements for casting. Silicon carbide 10 % and Boron carbide 2.5 % were volume based reinforced in to aluminum 7029. The cast specimen of 30 mm diameter is cut using wire-EDM in to circular plates of 12 mm thickness.

Rr

Tool Preparation

The tool material used for the experimentation is electrolytic copper tool (99.9%). The diameter of the tool electrode is 20mm and its total length is 25 mm.

Experimental Setup

In this experiment, the entire work is done by the Electric Discharge Machine and its model is ELECTRONICA- PS 50ZNC which is a die-sinking type. It has a servo-head with constant gap and it also requires positive polarities for electrodes to conduct this experiment. The dielectric fluid used is commercial grade EDM oil which has the specific gravity of about 0.763 and freezing point of about 94°C. It also has a copper tool along with a pressure 0.2 kgf/cm2. The positive polarity of electrodes is used in this experiment and in positive mode the pulsed discharge current is used at different steps.

WORK MATERIAL DETAILS

Work material – AMMC

Work material size–32mm Dia 12mm thickness

Design of Experiment

Table 2: Process parameters and their levels

S. No	Pulse on time (µs)	Pulse off time (µs)	Gap current (amps)
1	10	7	8
2	20	8	10
3	50	9	12
4	100	10	14

An Orthogonal Array L_9 Formation

Table 3: L16 Array formation

T.no	Desig	Pulse on time (µs)	Pulse off time (µs)	Gap current I_P (amps)
1	$A_1B_1C_1$	10	7	8
2	$A_1B_2C_2$	10	8	10
3	$A_1B_3C_3$	10	9	12
4	$A_2B_1C_2$	10	10	14
5	$A_2B_2C_3$	20	7	10
6	$A_2B_3C_1$	20	8	12
7	$A_3B_1C_3$	20	9	14
8	$A_3B_2C_1$	20	10	8
9	$A_3B_3C_2$	50	7	12
10	$A_3b_2c_4$	50	8	14
11	$A_3B_2C_1$	50	9	8
12	$A_3B_4C_2$	50	10	10
13	$A_4B_1C_3$	100	7	14
14	$A_4B_2C_1$	100	8	8
15	$A_4B_3C_2$	100	9	10
16	$A_4B_4C_3$	100	10	12

Experimental Data

Table 4: Experimental Data of the EDM process

S. No	Designation	T ON	T OFF	AMPS	RA µm	MRRx10^{-3} gm/min	Mt min
1	$A_1B_1C_1$	10	7	8	2.134	1.543	72
2	$A_1B_2C_2$	10	8	10	1.975	1.519	78
3	$A_1B_3C_3$	10	9	12	2.472	2.124	68
4	$A_2B_1C_2$	10	10	14	2.322	2.178	51
5	$A_2B_2C_3$	20	7	10	3.287	4.306	43
6	$A_2B_3C_1$	20	8	12	2.835	2.182	56
7	$A_3B_1C_3$	20	9	14	2.700	2.792	61
8	$A_3B_2C_1$	20	10	8	3.512	2.898	46
9	$A_3B_3C_2$	50	7	12	3.416	4.737	43
10	$A_3b_2c_4$	50	8	14	3.356	4.157	49
11	$A_3B_2C_1$	50	9	8	3.334	3.624	47
12	$A_3B_4C_2$	50	10	10	4.016	0.052	40
13	$A_4B_1C_3$	100	7	14	4.837	7.703	25
14	$A_4B_2C_1$	100	8	8	4.626	4.861	32
15	$A_4B_3C_2$	100	9	10	4.332	6.237	38
16	$A_4B_4C_3$	100	10	12	3.976	5.239	41

Roughness Response for Each Level of the Process Parameter

Table 5: Response Table for Signal to Noise Ratios-Smaller is better

LEVEL	T ON	T OFF	AMPS
1	-6.918	-10.320	-9.521
2	-9.731	-9.696	-10.264
3	-10.930	-9.920	-10.687
4	-12.930	-10.573	-10.038
DELTA	6.011	0.878	1.166
RANK	1	3	2

Table 6: Analysis of Variance for RA

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
T ON	3	10.2328	3.41092	30.43	0.001	89
T OFF	3	0.2217	0.07390	0.66	0.606	2
AMPS	3	0.4179	0.13930	1.24	0.374	4
ERROR	6	0.6725	0.11208			5
TOTAL	15	11.5448				100

Model Summary

S R-sq R-sq(adj) R-sq(pred) 0.334776 94.18% 85.44% 58.58%

Regression Equation

Ra = 3.3206 - 1.095 Ton_10 - 0.237 Ton_20 + 0.210 Ton_50 + 1.122 Ton_100 + 0.098 Toff_7 - 0.123 Toff_8 -

0.111 Toff_9 + 0.136 Toff_10 - 0.251 Curr_8 + 0.082 Curr_10 + 0.186 Curr_12 - 0.017 Curr_14 Main Effects Plot for SN ratios

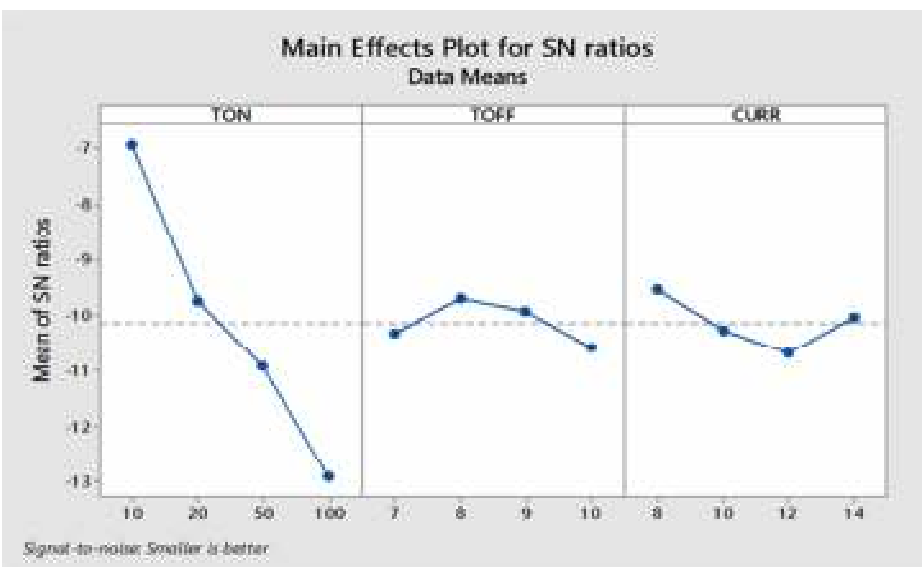

Figure 2: Main effects plot for SN ratios

Machining Time for Each Level of the Process Parameter

Table 6: Response Table for Signal to Noise Ratios-MT--Smaller is better

Level	T ON	T/OFF	AMPS
1	-36.45	-32.61	-34.45
2	-34.15	-34.18	-33.54
3	-32.99	-34.35	-33.17
4	-30.48	-32.93	-32.91
Delta	5.97	1.74	1.55
Rank	1	2	3

Table 7: Analysis of Variance of MT

Source	DF	Seq SS	Adj MS	F	P	% of contribution
T ON	3	2327.2	775.75	12.09	0.006	74
T/OFF	3	292.3	97.42	1.52	0.303	9
AMPS	3	137.2	45.75	0.71	0.579	4
Error	6	385.0	64.17			13
Total	15	3141.8				100

Model Summary

S R-sq R-sq(adj) R-sq(pred) 8.01041 87.75% 69.36% 12.86%

Regression Equation MT = 49.38 + 17.88 T-ON_10 + 2.12 T-ON_20 - 4.63 T-ON_50 - 15.38 T-ON_100 - 3.63 T- OFF_7+ 4.38 T-OFF_8 + 4.13 T-OFF_9 - 4.87 T-OFF_10 + 4.62 AMPS_8 + 0.38 AMPS_10- 2.12 AMPS_12 -

2.87 AMPS_14

Main Effects Plot for SN Ratio

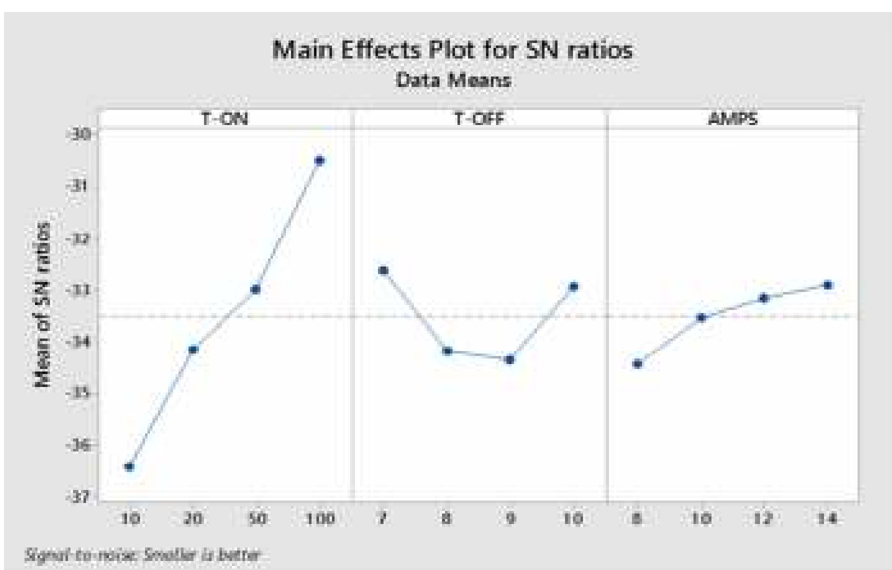

Figure 3: Main effects plot for SN ratios

MRR for Each Level of the Process Parameter

Table 8: Response Table for MRR-Larger is better

Level	T ON	T/OFF	AMPS
1	5.176	11.923	9.028
2	9.405	9.130	1.633
3	2.847	10.636	10.757
4	15.438	1.177	11.447
Delta	12.591	10.746	9.814
Rank	1	2	3

Table 9: Analysis of Variance

Source	DF	Seq SS	Adj MS	F	P	% Of Contribution
T ON	3	37.549	12.516	8.30	0.015	65
T/OFF	3	8.458	2.819	1.87	0.236	13
AMPS	3	3.485	1.162	0.77	0.551	6
Error	6	9.051	1.508			16
Total	15	58.543				100

Model Summary

S R-sq R-sq(adj) R-sq(pred) 1.22820 84.54% 61.35% 0.00%

Regression Equation

MRR = 3.509 - 1.669 T-ON_10 - 0.465 T-ON_20 - 0.367 T-ON_50 + 2.501 T-ON_100 + 1.063 T-OFF_7- 0.330 T-OFF_8 + 0.185 T-OFF_9 - 0.918 T-OFF_10 - 0.362 AMPS_8 - 0.481 AMPS_10+ 0.145 AMPS_12 + 0.698 AMPS_14

Main Effects Plot for SN Ratio

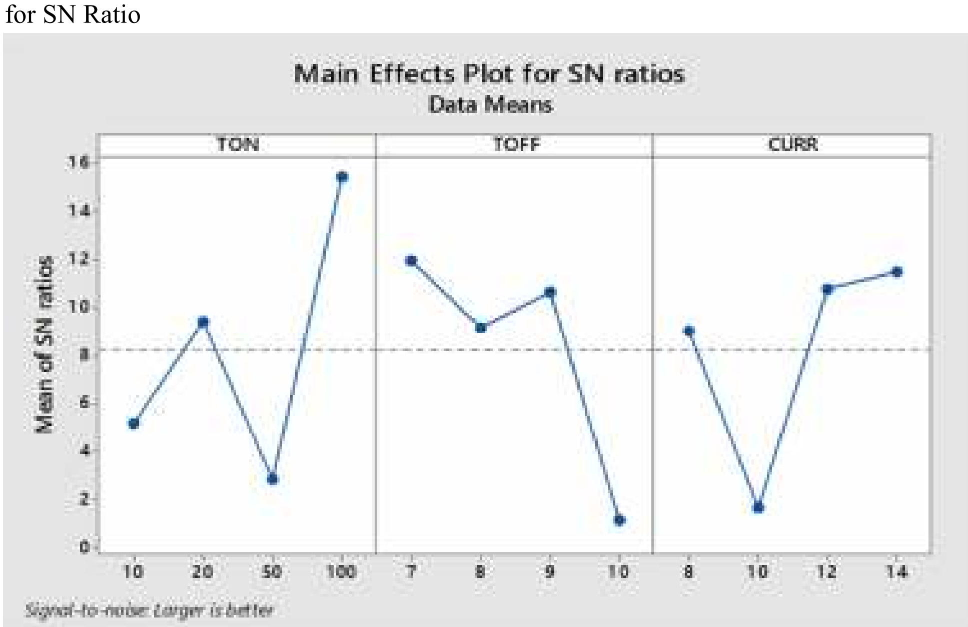

Figure 4: Main effects plot for SN ratios

RESULTS AND CONCLUSION

The major objective of this work is to investigate the machining of hybrid aluminum metal matrix composite using EDM. There are three processing parameters are varied in this study are namely Pulse on time, Pulse off time and ampere rating in the influence on the responses MRR, Machining timing and Ra. Based on the experimental results the following conclusions were drawn:

Optimal Control Factor

1. Surface Roughness-A1(Pulse on time -10μs)B3(Pulse off time -9 μs)C2(Amps-10)
2. Machining Timing- A1 (Pulse on time -10μs) B3(Pulse off time -9 μs)C2(Amps-10)
3. Material Removal Rate- A1(Pulse on time -10μs)B2(Pulse off time -8 μs)& C3(Amps-12)

Minimum Surface finish and machining timing were held at through lower level pulse on time and lower rating of amps. MRR were held at through lower level pulse on time and Maximum rating of amps.

Percentage Contribution of Process Parameter

1. Surface Roughness- Pulse on time 89%
2. Machining Timing -Pulse on time 74%
3. Material Removal – Pulse on time 65%

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