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Investigation of process parameters of AMEDM on Al/SiC composite using Taguchi approach

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ABSTRACT

The present study examines the abrasive mixed electrical discharge machining (AMEDM) of aluminium composites. Taguchi method has been used to optimize the material removal rate (MRR) and tool wear rate (TWR) considered as performance response for composite machining using AMEDM. In this analysis, boron carbide (B_4C) abrasive particles were mixed with different concentration to the kerosene oil that acts as a dielectric fluid (DF). It has been found that with the addition of B_4C powder, MRR is increased and TWR is decreased. Based on S/N ratio analysis, results showed that the MRR in machining of through holes with AMEDM on composites is significantly influenced by abrasive concentration and peak current. Concentration of abrasive particles has a significant impact on the TWR. Optimum process parameters are found based on S/N ratio analysis, For MRR, value are specified as pulse-on-time (A2) 120 μs, peak current (B3) 9 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D2) 40 μs and for TWR, value are specified as pulse-on-time (A3) 150 μs, peak current (B2) 6 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D3) 50 μs.
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1. Introduction

EDM is an advanced machining process used to machine conductive materials, regardless of its hardness [1]. It works on the principle of thermo-electric erosion where sparks occur between two electrodes, i.e. the workpiece (anode) and the tool electrode (cathode), under the influence of DF, to extract or cut material. There are many variant of this method and it has been used to cut many kinds of hard-to-cut materials and to machine typical features and shapes. EDM has been used widely in recent years as an alternative to traditional techniques for machining of composites in the applications of aerospace and automotive industries. In normal EDM, it is difficult to achieve a higher MRR, and it is often producing poor surface quality. Abrasive powder mixing improves the dielectric's insulating ability, which eliminates its regular ionization and helps to achieve better efficiency. The powder-mixed EDM and the use of silicon particles as dielectric in de-ionized water were worked on by Kansal [2]. Analysis based on response surface methodology (RSM) resulted in a better surface finish and an increased MRR.

Researcher successfully achieved over 40 percent improvement in MRR in a recent study when machining D2 steel by powder-mixed EDM [3]. Improvement in surface quality in terms of crack density and recast layer reduction was obtained by Long [4] after fine machining of die steel by mixed titan powder EDM and also investigated the important role of various DFs, which is affecting the MRR [5]. Experimental trails were conducted based on L_9 OA for machining of SS 304 grade material through EDM process and corresponding results are studied [6]. The concentration of micro-cracks on the workpiece and sludge was found to generate increases compared to kerosene using distilled water as DF. The MRR is higher and the TWR is lower compared to kerosene when distilled water is used as a DF. The effect of process parameters on the machining of composites by using EDM [7]. The findings showed that with an increase in relative gap voltage, peak current and pulse-on- time, MRR becomes higher and decreases with an increase in SiC abrasive percentage. With an increase in both pulse

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Table 1
The levels of machining parameters.

Symbol	Factors	Level 1	Level 2	Level 3
A	Pulse-on-time (μs)	90	120	150
B	Peak current (A)	3	6	9
C	Concentration of B4C powder (gm/l)	0	10	20
D	Pulse-off-time (μs)	30	40	50

Table 2
L_9 OA design with output values.

Experimental No.	A	B	C	D	MRR(gm/min)	TWR(gm/min)
1	90	3	0	30	0.0023	0.0003
2	90	6	10	40	0.0027	0.0030
3	90	9	20	50	0.0037	0.0033
4	120	3	10	50	0.0047	0.0013
5	120	6	20	30	0.0053	0.0014
6	120	9	0	40	0.0040	0.0004
7	150	3	20	40	0.0020	0.0017
8	150	6	0	50	0.0027	0.0020
9	150	9	10	30	0.0037	0.0023

Experiments were conducted using Taguchi OA design as given in Table 2, and responses are reported (MRR and TWR).

Table 3
Response table-S/N for TWR and MRR.

Levels	Control Factors							
	A	B	C	D	A	B	C	D
	MRR in gm/min				TWR in gm/min			
Level 1	−50.92	−52.60	−50.85	−50.26	56.85	61.19	64.13	60.10
Level 2	−49.61	−50.71	−50.36	−51.25	60.92	53.84	53.65	57.94
Level 3	−51.33	−48.56	−50.66	−50.36	54.05	56.78	54.03	53.78
Delta	1.72	4.04	0.49	0.99	6.87	7.35	10.48	6.32

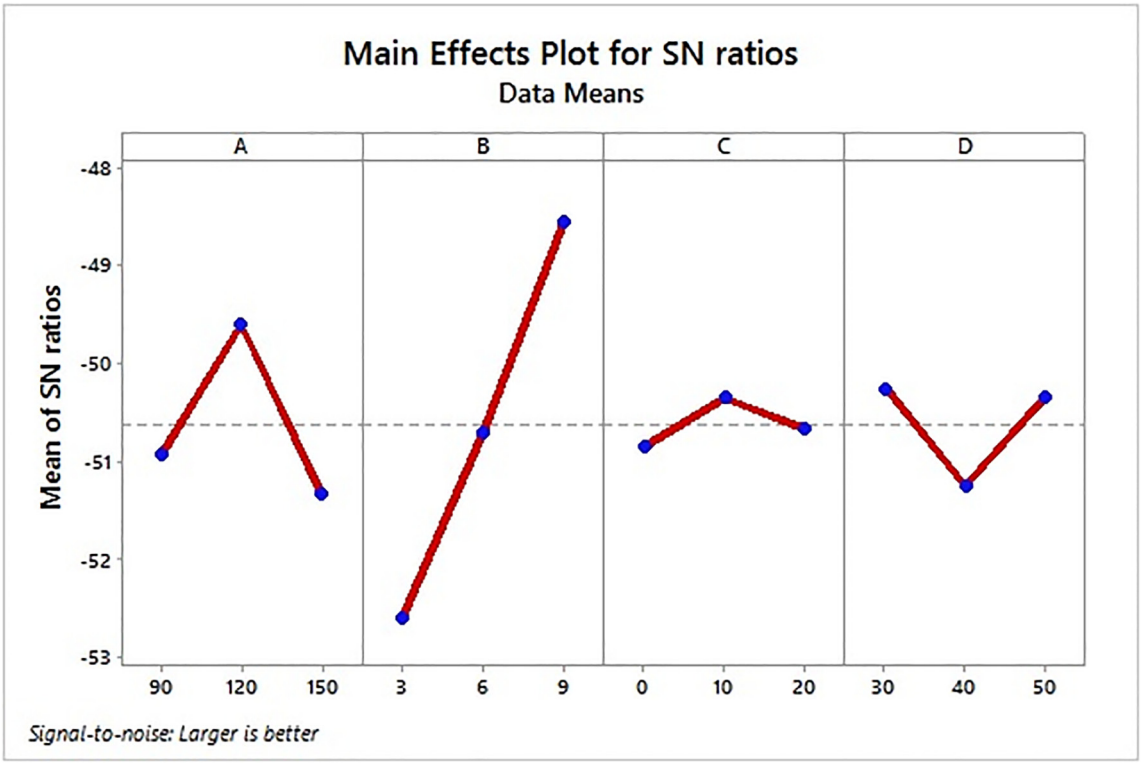


Fig 1. MRR effect plot for S/N ratio.

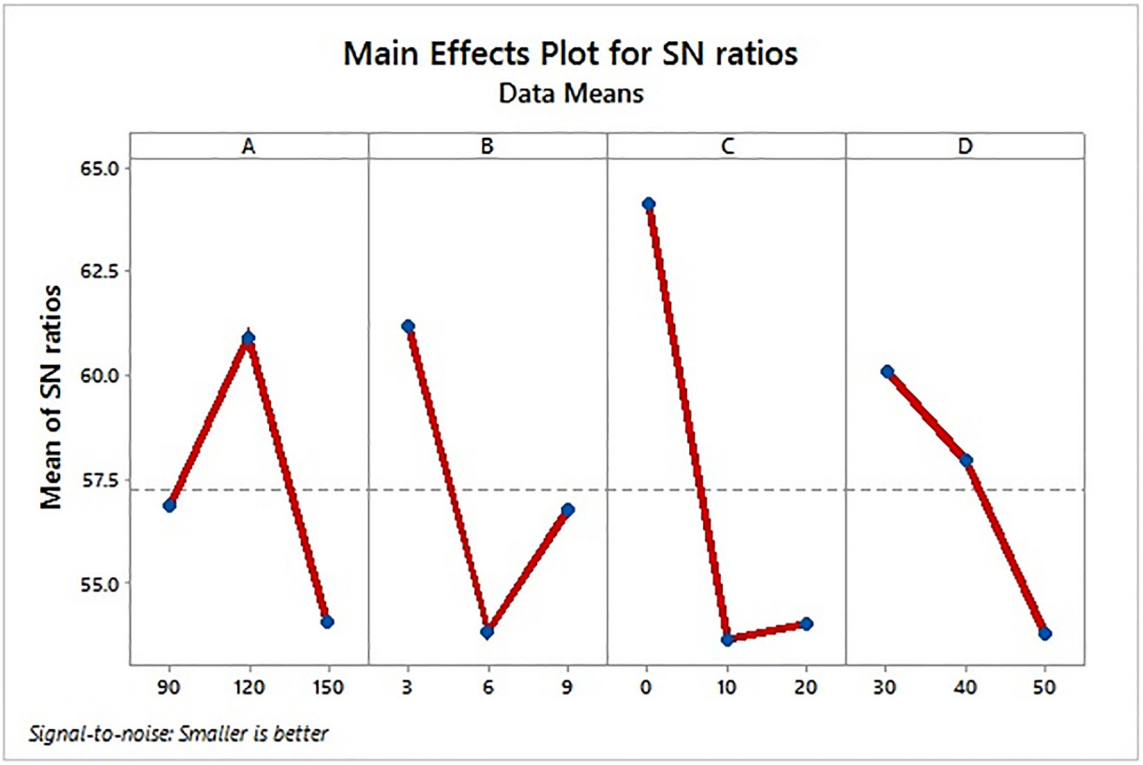


Fig 2. TWR effect plot for S/N ratio.

–on – time and peak current, the TWR becomes higher and decreases with an increase in both SiC percentage and gap voltage. With the increase in pulse-on-time, SiC percentage, gap voltage, peak current, the surface roughness increases.

The literature review reveals that abrasive powder-mixed EDM has potential and also machining of composites is very limited. It also indicates that it is important to do some further future research on the machining of other difficult-to-cut materials like alloys and composites. In present study, it fulfills the research gap and investigates the effect and optimization of process parameters on MRR, TWR and SR through AMEDM machining of Al composite.

2. Experimentation

In the existing EDM unit, the set-up was developed for mixing B_4C abrasives. A new mild steel tank has been constructed in which kerosene used as the DF is applied to 10 gm/l and 20 gm/l B_4C powders. Electrical pump with a small nozzle is used for proper mixing of the powders in the DF. There are several variables that affect the EDM process [8]. The working material used for this study was Aluminium 6026 with 10% silicon carbide composite fabricated by stir casting process. Peak current, pulse-on-time, concentration of abrasive particles and pulse-off-time are the process parameters considered for this machining process [9]. For experimental design, Minitab 18 software is used. Table 1 represents the Taguchi's L_9 orthogonal array. The values of factors and levels of factors are considered based on preliminary experiments and it is outlined in Table 2 [10].

3. Optimization

The machining process aims to minimize the TWR and maximize the MRR is the aim of this machining process [11–13]. A higher-the-better criterion is used for MRR and a lower-the-better criterion is used for TWR and corresponding Eqn. are expressed in (1) & (2).

For Higher- the- better:

$$\frac{S}{N_{\max}} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y_i^2}\right) \quad (1)$$

For Lower- the- better:

$$\frac{S}{N_{\min}} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}Y_i^2\right) \quad (2)$$

3.1. "S/N" ratio - analysis

An S/N response table is used to perform impact analysis of machining variables such as peak current, pulse-on-time, concentration of abrasive particle and pulse-off-time of MRR and TWR. Table 3 infers the response tables of "S/N" ratio for TWR and MRR.

As per "S/N" ratios values are presented in Figs. 1 & 2 for MRR & TWR, the Figure shows the best level and factor for MRR value are specified as pulse-on-time (A2) 120 μs, peak current (B3) 9 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D2) 40 μs .

Likewise, the best level and factor for TWR value are specified as pulse-on-time (A3) 150 μs, peak current (B2) 6 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D3) 50 μs.

4. Conclusion

Present work on Al composite AMEDM with the use of abrasive B_4C particles in the DF. The following conclusions have been drawn on the basis of the experimental study:

- o Addition of B_4C in DF improves the MRR of AMEDM of Al composite.
- o It is favourable for the better MRR to increase peak current, but is negligible for the TWR.
- o For MRR, value are specified as pulse-on-time (A2) 120 μs, peak current (B3) 9 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D2) 40 μs.
- o For TWR, value are specified as pulse-on-time (A3) 150 μs, peak current (B2) 6 A, concentration of abrasive particle (C2) 10 gm/l and pulse-off-time (D3) 50 μs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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