

A STUDY ON THE EDM OF Al7075+3Wt%SiC+3Wt% B₄C HYBRID MMC

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Abstract

The objective of the project is to investigate the effect of current, pulse on time and pulse off time. For the proposed work Material removal rate (MRR) and Tool wear rate (TWR) were chosen as responses and Current, Pulse on time and pulse off time were chosen as process parameters. Hybrid Aluminium Silicon Carbide (Al 7075 + 3wt. % of SiC_p + 3wt. % of B₄C) is used as work material and copper is used as tool material. Design of experiment technique is employed for the experimentation. The mathematical models are prepared by Response Surface Methodology (RSM) technique and Box Behnken Design (BBD) is selected to design the matrix for different combination of process parameters. After completion of the experiments analysis was done using analysis of variance (ANOVA) for 90% confidence level.

Keywords: Current, Pulse on time, Pulse off time, Material removal rate (MRR), Tool wear rate (TWR), Design of experiments (DOE), Response surface methodology (RSM), Box-Behnken design (BBD), Analysis of variance (ANOVA).

1. INTRODUCTON

In Advance Manufacturing Industries now a day's advance materials are becoming very popular and important because of their scope, their properties and their applications. They have got superior properties like high hardness, high strength, thermal resistance, high fatigue strength etc. [1, 2] due to these properties these material have got wide range of applications in automotive industry, aeronautical industry, manufacturing of wind turbine blades, fiber glass and tubes etc. [3, 4] therefore it's become necessary to develop an efficient and accurate methods for the machining or operating such advanced composite materials with high accuracy. [1]

However the improved properties of Al/SiCB₄C present heavy challenge to the manufacturing engineers. It is necessary to select the appropriate method for the machining of this material with considering the required accuracy. It is difficult to achieve the required accuracy, surface finish quality with conventional machining processes, but it can be possible to achieve all those retirements by using non-conventional machining process. [4] So we have decided to select the non-conventional machining process with considering all these factors. Electro Discharge machining is one of the best methods for the machining of these composite materials.

2. EXPERIMENTAL WORK

The work piece material which we have used was fabricated HMMC of Al7075 reinforced with 3 wt % of silicon carbide and 3 wt % of boron carbide particulates by using stir

casting method. For the experiment the work piece was cut in size of 50 x 50 x 6mm. Copper rod is machined properly to 8mm diameter which is used as electrode material. [4]

The following steps have followed during conducting the experiment.

1. During experiment tool electrode is fixed at negative polarity and work piece is clamped on positive polarity.
2. The initial weight of work piece and tool electrode is taken before the experiment.
3. The work piece i.e. Al 7075+ 3wt % SiC+ 3wt % B₄C is mounted on the work table and at a desired position it is clamped with the help of clamping system provided. The tool electrode also clamped in to the tool holder.
4. Set the parameters of experiments which we have found with the help of Design of Matrix.
5. Start the pump to fill the die electric fluid into the working tank.
6. Finally start the machine and conduct the machining operation for the selected time duration. In this experiment we have conducted the experiments for 3 minutes.
7. After 3 minutes stop the machine and take off the work piece as well as the tool electrode and again weighed it.
8. The difference between initial weight and final weight gives the MRR and TWR in grams per minute.
9. By following the above procedure the set of experiments were carried out for the different set of parameters.

2.1 Tool Material

In the present experiment we have chosen the electrode or tool material as copper for the machining process. Copper (99.9% pure) is a material which is easily available. The main reason to selecting copper as electrode material is its excellent properties such as electrical conductivity. It is a ductile and malleable material, a good conductor of heat and when it very pure it will be a very good conductor of electricity. Its symbol is Cu and atomic number is 29. [5]

Table 1 Properties of copper

Property	Thermal Conductivity (W/Mk)	Melting Point ($^{\circ}$ C)	Density (Gm/Cm ³)	Electrical Resistivity (Ohm-Cm)	Specific Capacity (J/G $^{\circ}$ C)
Copper	391	1083	8.9	1.69	0.385

2.2 Conduction of Experiments According to Design of Matrix for the Evaluations Response Variables

According to the design of experiments 30 sets of experiments were carried out on the work piece i.e. Al7075+3wt%SiC+3wt%B₄C with the help of copper tool, after every reading the initial weight and final reading has noted down in order to find the responses like MRR and TWR.

$$\text{MRR} = \frac{\text{Initial wt of W/P} - \text{Final wt of W/P}}{\text{Time}} \text{ gms/min}$$

$$\text{TWR} = \frac{\text{Initial wt of Tool} - \text{Final wt of Tool}}{\text{Time}} \text{ gms/min}$$

2.3 Selection of Machining Parameters and Their Levels for the Experimentation

The experiments were carried out on the basis of Response surface methodology by considering three controllable parameters. The parameters we have selected are current, pulse on time and pulse off time. Each parameter has different levels and that will be studied and selected as shown in Table 2. [6,9]

Table 2 Parameters and their Ranges

Machining parameters	Uncoded values	Coded values	Levels			Ranges
			Low (-1)	Mid (0)	High (1)	
Current	I	X ₁	5	6	7	1 to 20A
Pulse on time	P _{on}	X ₂	20	40	60	0 to 99 μ s

Pulse off time	P _{off}	X ₃	2	4	6	0 to 9 μ s
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2.4 Design of Experiments (DOE)

The present experiments are conducted based on the influence of three input process parameters like current (I), pulse on time (P_{on}) in microsecond (μ S) and pulse off time (P_{off}) in microsecond (μ S) proposed by Three level Box Behnken Design (BBD) method for the 30 sets of readings.

3. RESULTS AND DISCUSSIONS

3.1 Mathematical Models for MRR and TWR [4]

For the work material and electrode material, the corresponding coefficient terms and mathematical models for MRR and TWR are developed with the help of these significant values.

Mathematical Model for MRR

$$Y_1 = -0.433980 + 0.101266X_1 + 0.004437X_2 - 0.005805X_1^2 - 0.000018X_2^2 - 0.000197X_1X_2 - 0.000398X_1X_3 - 0.000533X_2X_3$$

Mathematical Model for TWR

$$Y_2 = -0.009835 + 0.003511X_1 + 0.001247X_3 - 0.000002X_1X_2 - 0.000072X_1X_3 + 0.000002X_2X_3$$

In above equations X₁X₂X₃ are the coded values for current, pulse on time and pulse off time respectively. [10]

3.2 Estimation of Regression Coefficient for MRR and TWR

The values which we got from the experiment are entered in the Minitab software and the Response surface design was analyzed. The following tables represent the Estimation of Regression coefficient for MRR and TWR obtained from Minitab software. In the table some of P- values are marked with * mark, this indicates that the term is significant and is affecting the process with their corresponding coefficients. The confidence level for the experiments was set to 90%. [9]

Table 3 Estimated Regression Coefficients for MRR in gms/min [8]

Term	Coef	SE Coef	T	P
Constant	-0.433980	0.115683	-3.751	0.001*
Current (I)	0.101266	0.035387	2.862	0.010*
P _{on} Time	0.004437	0.001049	4.229	0.000*
P _{off} Time	0.043313	0.010491	4.129	0.001*
I * I	-0.005805	0.002872	-2.021	0.057*
P _{on} * P _{on}	-0.000018	0.000007	-2.501	0.021*

$P_{off} * P_{off}$	-0.001704	0.000718	-2.374	0.028*
$I * P_{on}$	-0.000197	0.000138	-1.426	0.169
$I * P_{off}$	-0.000398	0.001380	-0.289	0.776
$P_{on} * P_{off}$	-0.000533	0.000069	-7.734	0.000*

S = 0.00780378 PRESS = 0.00248777
 R-Sq = 92.65% R-Sq(pred) = 84.99% R-
 Sq(adj)=89.34%

The P- Value decides the significant terms. It can be defined as the smallest level of significance that would lead to rejection of null hypothesis. As we had set the confidence level as 90% then the P- value should be Equal to or less than 0.10. For the work material and electrode material, the corresponding coefficient terms and mathematical models for MRR and TWR are developed with the help of these significant values.

Table 4 Estimated Regression Coefficients for MRR in gms/min

Term	Coef	SE Coef	T	P
Constant	-0.009835	0.003760	-2.616	0.017*
Current (I)	0.003511	0.001150	3.052	0.006*
P_{on} Time	-0.000132	0.000034	-3.880	0.001*
P_{off} Time	0.001247	0.000341	3.656	0.002*
$I * I$	-0.000236	0.000093	-2.527	0.020*
$P_{on} * P_{on}$	0.000001	0.000000	5.884	0.000*
$P_{off} * P_{off}$	-0.000101	0.000023	-4.335	0.000*
$I * P_{on}$	-0.000002	0.000004	-0.502	0.621
$I * P_{off}$	-0.000072	0.000045	-1.603	0.125
$P_{on} * P_{off}$	0.000002	0.000002	0.711	0.485

S = 0.000253626 PRESS = 3.279512E-06
 R-Sq = 90.14% R-Sq(pred) = 74.87%
 R-Sq(adj) = 85.71%

3.3 Effect of Process Parameters on MRR and TWR.

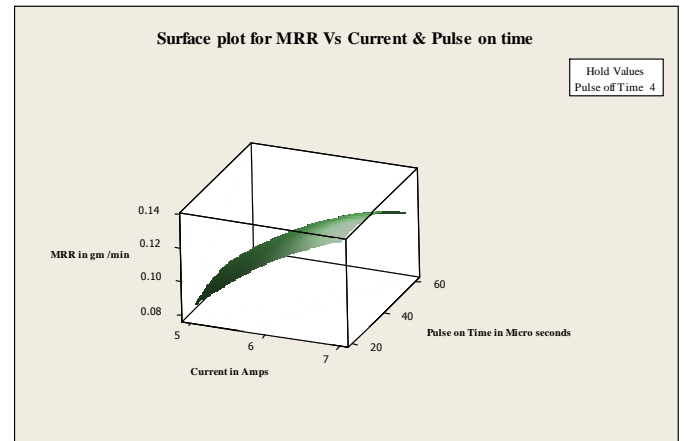


Fig 1.a Surface plot for MRR vs I & P_{on}

Fig. 1.a shows that surface plot MRR Vs current and pulse ON Time. As the current increases MRR goes on increasing. For current 5amp, MRR is 0.082 grams/min and for 6 Amps MRR is 0.11grams/min and for 7 Amps MRR is 0.13 grams/min. MRR goes on increasing with pulse ON time at 20 μ seconds MRR is 0.11grams/min, similarly for pulse ON time 40 μ seconds MRR is same but for pulse on time 60 μ seconds MRR is around 0.10 grams/min. MRR is High For high current at 7 amp and low pulse ON 20 μ seconds. This takes place because of the fact of discharge energy is increased to facilitate the activity of melting, vaporization and advancing large impulsive force in the spark gap thereby increasing MRR.[4]

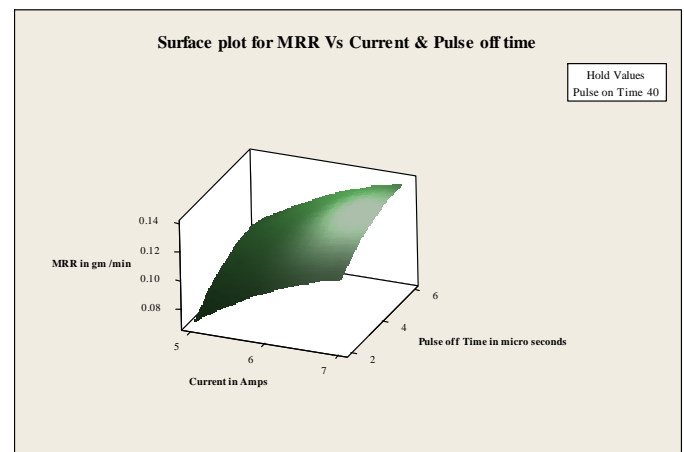


Fig1.b Surface plot for MRR vs I & P_{off}

The Fig 1.b shows the surface plot for MRR Vs current and pulse off time. According to the graph as the current increases the MRR increases as well as it also increases with pulse off time.

MRR is achieved 0.11 grams/min for pulse off time 2 μ seconds similarly for the mid value of pulse off i.e. 4 μ seconds it is 0.115 grams/min. MRR is high (0.1638 grams/min) for high current (7 Amp) and high pulse off time (6 μ seconds).

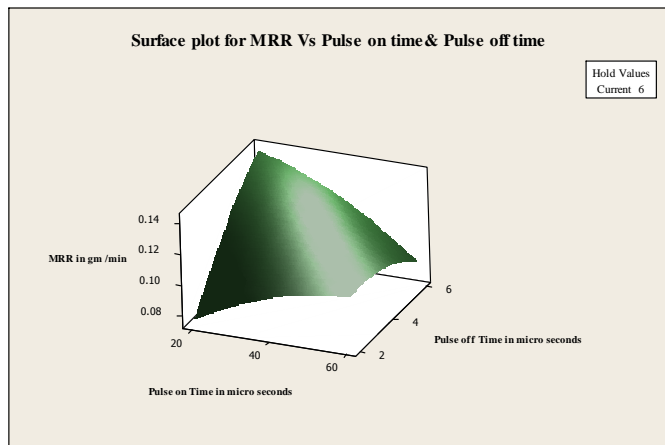


Fig 1.c Surface plot for MRR Vs P_{on} & P_{off}

Fig.1.b shows the surface plot for MRR Vs pulse on time and pulse off time. MRR goes on increasing with pulse off time but decreases with pulse on time. According to fig MRR is high (0.1489 grams/min) for lower pulse on time (20 μ seconds) and pulse off time (6 μ seconds).

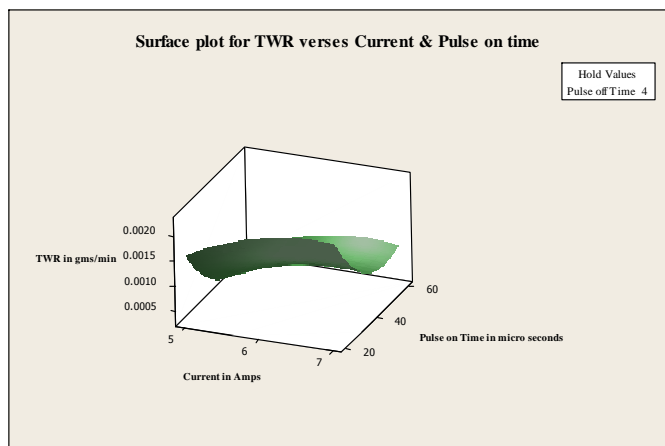


Fig 2.a Surface plot for TWR vs I & P_{on}

Fig 2.a depicts the surface plot for TWR Vs current and pulse on time. As shown in fig as the current increases, TWR also increases. For current 5 Amp TWR is 0.0006 μ seconds, for 6 Amp it is 0.0011 μ seconds and for 7 Amp 0.0011 μ seconds. As the pulse off time increases a TWR decrease till mid value then becomes constant. For 20 μ seconds pulse on time TWR is 0.0019 grams/min and for 40 μ seconds TWR is 0.0007 grams/min and then remains constant. TWR is low (0.0001) for high current (5 Amps) and high pulse on time (40 μ seconds). When the larger peak current takes place it generates larger discharging energy which will cause for higher tool wear rate. [7]

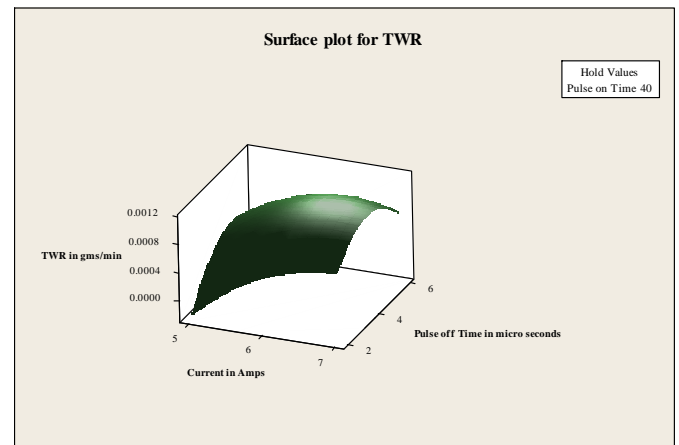


Fig2.b Surface plot for TWR vs I & P_{off}

Fig 2.b shows that the surfaces plot for TWR Vs current and pulse off time. As the Pulse off increase TWR also increases till 4 μ seconds after it starts decreasing. For pulse off time i.e. 2 μ seconds TWR is 0.0006 grams/min, for the pulse of time 4 μ seconds TWR is 0.0012grams/min, and for pulse off time 6 μ seconds TWR is 0.0008 μ seconds

Fig 2.c shows the surface plot for TWR VS pulse on time and pulse off time. TWR is low (0.0001 grams/min) for higher (60 μ seconds) pulse on time and lower (2 μ seconds) pulse off time. Pulse on and pulse off time is a very significant factor for TWR.

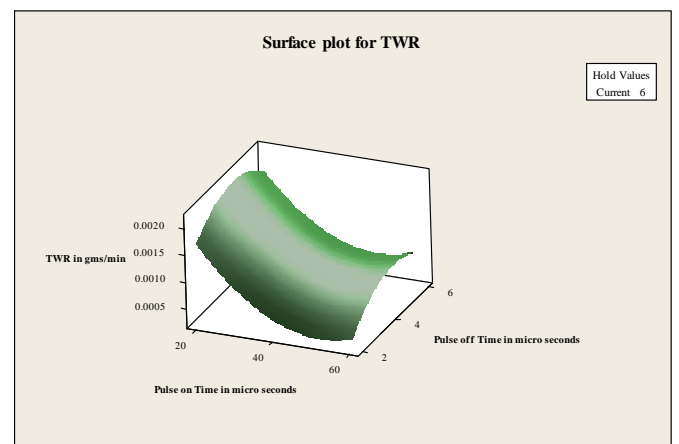


Fig 2.c Surface plot for TWR Vs P_{on} & P_{off}

4. CONCLUSION

Based on the results and analysis discussion, the results were presented along the graphs. Experimental investigation on the effect of MRR and TWR generated by an EDM machining process on Al7075+3wt%SiC+3wt%B₄C. Based on the Experimental results the following can be concluded:

1. MRR is influenced by current and pulse on time. As the current and pulse on time increases MRR also increases till some extent but further increase in pulse on time MRR starts decreases.
2. TWR is influenced by current and pulse on time. As the current increases TWR an also increase till some extent and then starts decreasing.

3. The first optimum combination of parameters setting is current 7, pulse on time 40 and pulse off time 6 for maximizing the MRR and minimizing the TWR and second optimum combination of parameters setting is current 5, pulse on time 40 and pulse off time 6 for maximizing the MRR and minimizing the TWR.
4. The predicted values match the experimental values with R^2 of MRR and TWR
5. The created mathematical models using Minitab software can be utilized to access MRR and TWR with low % error.
6. As the pulse off time increases the TWR increases.
7. With the 90% confidence level the mathematical models for MRR and TWR are well fitted.

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