Variation of electrode materials and parameters in the EDM of an AA7075-TiO_2 composite

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The present study was carried out to analyze the effect of process parameters during EDM machining of AA7075-10 wt.-% TiO_2 aluminum matrix composite (AMC). The composite was produced through stir casting. The EDM process parameters such as the electrode material (Cu, Br, EN-8), pulse current (5, 10 and 15 A), pulse ON time (300, 600 and 900 μs) and pulse OFF time (30, 60 and 90 μs) were chosen to study the effects on material removal rate, surface roughness and the electrode wear ratio. The experiment was carried out as per L27 orthogonal array based on Taguchi's design of experiments. Signal-to-noise ratio and analysis of variance were used to identify the contribution of each input parameters on the output responses of the EDM process. The experimental results shows that pulse ON time and pulse current are the most significant factors for the material removal rate; pulse ON time and electrode material are the most influencing parameters for surface roughness and the electrode wear ratio.

Article Information

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Aluminum and its alloys are lightweight materials with excellent mechanical properties such as high strength-to-weight ratio, high stiffness, low thermal expansion coefficient and better corrosion resistance as compared with other lightweight materials [1, 2]. Among the many aluminum alloy series, AA7075 (Al-Zn-Mg-Cu) gains more importance in the aerospace and automobile industries for the manufacturing of aircraft fittings, gears and shafts, missile parts, sports bicycle frame and defence applications due to its high tensile strength, high toughness and natural aging characteristics [3, 4]. Currently, many researchers are concentrating on metal matrix composites, due to their unique combination of properties [5]. Aluminum based metal matrix composites have been gaining rapid adoption in several industries and are said to be an attractive choice for various applications when compared with conventional aluminum alloys [6]. Stir casting, powder metallurgy, squeeze casting, centrifugal casting, infiltrations and spray deposition processes are generally used for manufacturing aluminum matrix composites (AMC) [7, 8]. Among those techniques, stir casting has been found to be the simplest, most economical and cost effective method of liquid state fabrication [9, 10]. Assorted hard and soft ceramic particles are introduced for producing AMCs. Among these, TiO_2 is a potential reinforcement material for AMCs [11]. Reinforcing TiO_2 particles in AA7075 matrix enhances the mechanical properties of AMCs [12]. Machining AMCs by conventional machining process is challenging and complicated because of its higher the hardness and poor thermal properties [13, 14]. Therefore, unconventional machining processes are most suitable for machining AMCs. Electric discharge machining (EDM) possesses excellent thermal erosion and is extensively used for machining difficult to machine materials and high strength temperature resistant alloys and also used to machine critical cavities in dies and molds, complex geometries in aerospace and automobile industries with greater tolerances [15-17]. Harmesh Kumar et al. analyzed the EDM of Al-10 wt.-% SiC metal matrix composites (MMC) and observed that powder concentration and peak current are the most predominant factors on the materials removal rate (MRR) and surface roughness (SR) [18]. Paras Kumar et al. optimized the EDM process parameters of Al6061-B_4C composites using Taguchi methodology and reported that current is the most prominently factor affecting the MRR and SR, while the electrode material is most important for the electrode wear ratio (EWR) [19]. Riaz Ahamed et al. reported the application of EDM to machine cast aluminum-SiC-B_4C and cast aluminum-SiC-glass hybrid MMCs on MRR and SR to the various EDM parameters [20]. Gopalakannan et al. investigated the effect of EDM parameters viz., pulse current, gap voltage, pulse ON time and pulse OFF time on MRR, EWR and SR during the machining of Al6063/10 wt.-% SiC-3 wt.-% Gr hybrid metal matrix composites and concluded that pulse current is a dominant parameter that affects all responses [21]. Senthilkumar et al. studied the recast layer evolved during the EDM processing of Al/TiC metal matrix composites and reported that flushing pressure plays a vital role in improving the MRR at higher discharge current and pulse duration levels [22]. Yan et al. used disklike electrodes for machining of Al_2O_3/AA6061 composites by rotary EDM and observed that the peak current and volume fraction of Al_2O_3 significantly affects the MRR, EWR and SR [23]. Mohan et al. analyzed the effect of the rotation of the electrode on the EDM of Al-SiC metal matrix composites [24]. Radhika et al. studied the EDM process of Alsi10Mg/3 wt.-% graphite/9 wt.-% alumina hybrid composites and derived that peak current is the most significant factor in SR and that flushing pressure is a dominant factor on MRR, whereas pulse ON time is affects tool wear [25]. Wuyi Ming et al. analyzed the influence of peak current, pulse ON time, pulse OFF time and servo voltage on the MRR and SR while machining AA/SiC composites [26]. Patel et al. investigated the EDM machining of different particle size of SiCp-Al composites and observed that servo speed is a most significant factor on MRR and EWR while the pulse on duration affected the taper [27]. Suresh kumar et al. investigated the influence of process parameters on the EDM of Al6351-SiC-B_4C hybrid MMCs and reported that the pulse current has a great influence on output responses such as MRR, EWR and SR [28]. Balbir singh et al. experimented on a machinability and surface modification of AA6061/10 wt.-% SiC MMCs using a brass electrode. They observed that a higher current and pulse on time setting produced a higher MRR and TWR [29].

The aim of the present investigation is to analyze the effect of EDM process parameters, namely electrode material, pulse current, pulse ON time and pulse OFF time on MRR, SR and EWR during the machining of an AA7075-10 wt.-% TiO_2 composite analyzed by using the Taguchi method. ANOVA was used to find the contribution of each input parameter on the output responses.

Experimental procedure

Aluminium alloy 7075 was selected as matrix material (Si 0.40, Cu 1.2-2.0, Mg 2.1-2.9, Mn 0.3, Zn 5.1-6.1, Ti 0.2, Cr 0.18-0.28, Fe 0.5 and Al balance in wt.-%), and TiO_2 was used as a reinforcement material. To produce an AA7075-10 wt.-% TiO_2 composite, 1 kg of AA7075 was placed into a graphite crucible and heated to 850 °C using an electrical furnace till the entire metal melted in the crucible. The furnace temperature was controlled by a digital controller. An electrical furnace coupled with a rotating impeller was used as a stirrer. The quantity of TiO_2 particles measured was preheated to 200 °C to remove moisture. The preheated TiO_2 particles were fed into the molten slurry. After the addition of a required quantity of TiO_2 particles, the slurry was stirred for 10 minutes at a speed of 280 rpm. Finally, the slurry was poured into a preheated mold and allowed to solidify at room temperature. The mechanical properties of the newly prepared AA7075-10 wt.-% TiO_2 composite were studied. The hardness of the composite was measured using a Vickers micro hardness tester (Wilson Wolpert Group, Germany). A micro tensile test was carried out as per ASTM E8-08 standard using a 10 KN capacity universal testing machine (UTM). The impact strength of the composite was evaluated by using an Izod impact testing machine (Model: AIT-300-N). The mechanical properties, such as yield strength, tensile strength, impact strength and micro hardness of the composite are given in Table 1.

The machining was performed using die sinking EDM (SPARKONIX INDIA). The experimental EDM setup is shown in Figure 1a. Kerosene was used as a dielectric fluid and its flushing pressure was 1.5 kg × cm^{-2} during machining process. Various electrode materials such as copper (Cu), brass (Br) and EN-8 were taken as one of the input parameters for the machining of the composite material. The electrode materials are shown in Figure 1b. These electrode materials were used in the form of cylindrical rods 12 mm in diameter and 80 mm in length. The properties of the electrode materials are given in Table 2. The size of the work piece was 100 mm × 100 mm × 10 mm plate.

The proper selection of input parameters is essential for the EDM machining process. Of the many input parameters of EDM, four input parameters were in particular influence EDM performance. Many researchers reported the following parameters as significant for the EDM process, these being electrode material, pulse current, pulse ON time and pulse OFF time [19]. These four process parameters on three levels are considered in the present study and are given in Table 3. The experiment was carried out as per L27 orthogo-

Yield strength (MPa)	Tensile strength (MPa)	Impact strength (J)	Hardness (VH)
176.35	215.13	122	151

Table 1: Mechanical properties of AA7075- 10 wt.-% TiO_2 composite

Electrode material	Thermal conductivity (W × (mK^{-1}))	Melting point (°C)	Electrical resistivity (Ω × m)	Specific heat capacity (J × (kg × K)$^{-1}$)
Copper	391	1085	1.67×10^{-8}	385
Brass	159	940	4.7×10^{-8}	380
EN-8	50	1510	1.71×10^{-7}	465

Table 2: Electrode materials properties

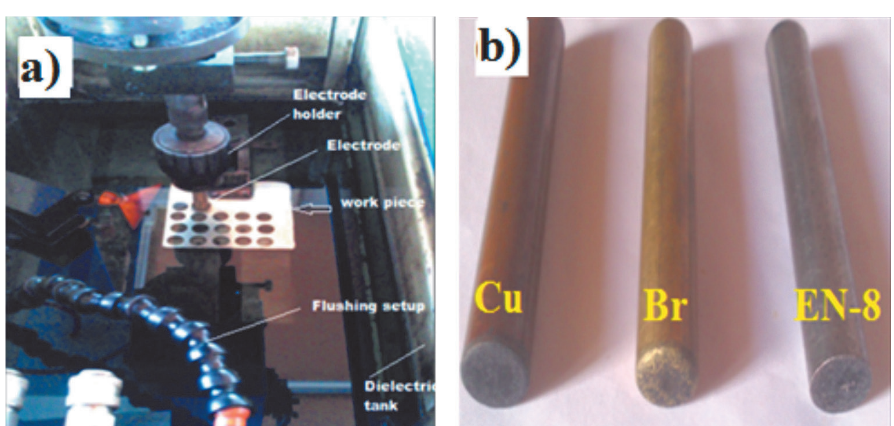


Figure 1: a) EDM experimental setup, b) electrode materials

nal array as shown in Table 4. For all the experiments, the depth of the machining was maintained at 3 mm. The output responses such as MRR, EWR and SR were considered for analyzing EDM machining performance. To calculate the MRR and EW (electrode wear), the ratio of the difference between the mass of the work piece and the electrode before and after machining within a period of time was determined. The EWR is calculated by the EW to the MRR. Surface roughness was measured for each machined surface by using a surface roughness tester (Mitutoya Talysurf SJ-210). The experimental results with their calculated S/N ratio are presented in Table 5.

The Taguchi technique is a much more attractive statistical tool for optimizing the process parameters in any machining process, and it can likewise reduce the number of experiments [30]. In this work, the experimental results were analyzed through Taguchi based signal to noise (S/N) ratio analysis. Normally, three types of quality characteristics are possible for evaluating the S/N ratio, namely: smaller-the-better, nominal-the-better and higher-the-better [31, 32]. Since we require the maximum MRR, minimum SR and EWR for this study, the higher-the-better characteristic was selected for the MRR and smaller-the-better characteristics was chosen for the SR and EWR by using the Equations (1) and (2). Analysis of Variance (ANOVA) is a standard statistical tool for determining the analysis of experimental data and is also commonly used to identify the performance on a group of process parameters under investigation [33, 34].

$$S / N \text{ ratio} = -10 \log_{10} (1/n) \sum_{k=1}^{n} \frac{1}{Y_{i,j}^{2}} \quad (1)$$

Table 3: Process parameters with their levels

Symbol	Process parameters	Units	Level		
			1	2	3
A	Electrode material	–	Cu	Br	EN-8
B	Pulse current	A	5	10	15
C	Pulse ON time	µs	300	600	900
D	Pulse OFF time	µs	30	60	90

Exp. No.	A	B	C	D	Electrode material	Pulse current (A)	Pulse ON time (µs)	Pulse OFF time (µs)
1	1	1	1	1	Cu	5	300	30
2	1	1	2	2	Cu	5	600	60
3	1	1	3	3	Cu	5	900	90
4	1	2	1	2	Cu	10	300	60
5	1	2	2	3	Cu	10	600	90
6	1	2	3	1	Cu	10	900	30
7	1	3	1	3	Cu	15	300	90
8	1	3	2	1	Cu	15	600	30
9	1	3	3	2	Cu	15	900	60
10	2	1	1	1	Br	5	300	30
11	2	1	2	2	Br	5	600	60
12	2	1	3	3	Br	5	900	90
13	2	2	1	2	Br	10	300	60
14	2	2	2	3	Br	10	600	90
15	2	2	3	1	Br	10	900	30
16	2	3	1	3	Br	15	300	90
17	2	3	2	1	Br	15	600	30
18	2	3	3	2	Br	15	900	60
19	3	1	1	1	EN-8	5	300	30
20	3	1	2	2	EN-8	5	600	60
21	3	1	3	3	EN-8	5	900	90
22	3	2	1	2	EN-8	10	300	60
23	3	2	2	3	EN-8	10	600	90
24	3	2	3	1	EN-8	10	900	30
25	3	3	1	3	EN-8	15	300	90
26	3	3	2	1	EN-8	15	600	30
27	3	3	3	2	EN-8	15	900	60

Table 4: Experimental layout using L27 orthogonal array

Exp. No.	Output responses			Signal- to-noise ratio		
	MRR (g × min^{-1})	SR (µm)	EWR (%)	MRR (dB)	SR (dB)	EWR (dB)
1	0.0292	8.257	43.441	-30.6923	-18.3364	-32.7580
2	0.0462	6.608	37.634	-26.7072	-16.4014	-31.5116
3	0.0315	10.113	41.865	-30.0338	-20.0976	-32.4370
4	0.0443	7.652	38.622	-27.0719	-17.6755	-31.7367
5	0.1133	6.211	29.595	-18.9154	-15.8632	-29.4244
6	0.1271	8.412	28.821	-17.9171	-18.4980	-29.1942
7	0.0247	3.171	57.581	-32.1461	-10.0239	-35.2056
8	0.1541	5.482	26.083	-16.2439	-14.7788	-28.3272
9	0.3077	6.471	19.080	-10.2375	-16.2194	-25.6116
10	0.0772	3.651	43.248	-22.2477	-11.2482	-32.7193
11	0.1138	4.385	41.203	-18.8772	-12.8394	-32.2986
12	0.1564	7.184	38.384	-16.1153	-17.1273	-31.6830
13	0.2242	3.307	32.743	-12.9873	-10.3887	-30.3024
14	0.1784	5.106	34.494	-14.9721	-14.1616	-30.7549
15	0.3279	6.862	30.917	-9.6852	-16.7290	-29.8039
16	0.0337	3.286	50.947	-29.4474	-10.3334	-34.1424
17	0.3819	4.274	29.865	-8.3610	-12.6167	-29.5033
18	0.6402	3.265	18.661	-3.8737	-10.2777	-25.4187
19	0.0410	4.519	37.200	-27.7443	-13.1008	-31.4109
20	0.0576	5.697	31.393	-24.7916	-15.1129	-29.9367
21	0.0632	8.475	29.898	-23.9857	-18.5628	-29.5128
22	0.0844	3.765	26.049	-21.4732	-11.5153	-28.3158
23	0.1764	4.377	17.564	-15.0700	-12.8235	-24.8925
24	0.2935	7.835	16.564	-10.6478	-17.8808	-24.3833
25	0.0376	4.168	41.888	-28.4962	-12.3986	-32.4418
26	0.2962	3.986	15.565	-10.5683	-12.0107	-23.8430
27	0.4495	5.854	11.333	-6.9454	-15.3491	-21.0869

Table 5: Experimental results with their S/N ratios

$$S / N\ ratio = -10\log_{10}(1/n)\sum_{k=1}^{n} Y_{i,j}^{2} \qquad (2)$$

with n: number of replications, Y_{ij}: observed responses value, i = 1, 2, 3.....n and j = 1, 2, 3.......k.

Results and discussion

Effect of machining parameters on the MRR. Figures 2a to 2d show the main effect of the process parameters, such as the electrode material, pulse current, pulse ON time and pulse OFF time on the MRR. It can be observed that an increase in pulse ON time and pulse current increases the MRR. An increase in pulse ON time increases the development of spark energy so that an increase in MRR is achieved. The mean S/N ratio for MRR is provided in Table 6. From the Table, pulse ON time and pulse current are most significant parameters for the MRR followed by the electrode material and pulse OFF time. The maximum MRR is attained for the combination of parameters ($A_2B_3C_3D_2$), which is to say, electrode material (Br), pulse current (15 A), pulse ON time (900 µs) and pulse OFF time (60 µs). Table 7 shows the results of ANOVA for the MRR. From the table, it can also be confirmed that pulse ON time and pulse current have the most significant parameters with a contribution of 29.31 % and 26.53 %, respectively followed by the electrode material at 14.25 % and pulse OFF time at 13.37 %. The similar results have already been reported for the EDM machining of Al 4032 reinforced with ZrB_2 and TiB_2 in situ composites [34]. The reason for this increase in the MRR is that the enhanced spark energy is increased into pulse current, thus improving heat generation. In this way, increased heat generation enhances spark erosion and thus a high MRR is obtained.

Effect of machining parameters on SR. The mean S/N ratio for the SR is given in Table 8. Pulse ON time is the most significant parameter for the SR followed by the electrode material and pulse current. Figures 3a to 3d show the main effect plot of the varied process parameters such as the electrode material, pulse current, pulse ON time and pulse OFF time on the SR. It can be clearly noticed that as pulse ON time increases, the spark energy delivered increases, causing craters to be produced on the machined work piece surface which result in a poor surface finish. The minimum SR is achieved at the optimum levels of parameters ($A_2B_3C_1D_2$), which is to say, electrode material (Br), pulse current (15 A), pulse ON time (300 µs) and pulse

Symbol	Process parameter	Level 1	Level 2	Level 3	max-min
A	Electrode material	-23.33	-15.17	-18.86	8.16
B	Pulse current (A)	-24.58	-16.53	-16.26	8.32
C	Pulse ON time (µs)	-25.81	-17.17	-14.38	11.43
D	Pulse OFF time (µs)	-17.12	-17.00	-23.24	6.25

Table 6: S/N ratios table for MRR

Source	DF	Adj SS	Adj MS	F- ratio	P-value	P (%)
Electrode material (A)	2	0.087588	0.043794	7.76	0.004	14.25
Pulse current (B)	2	0.163076	0.081538	14.45	0.000	26.53
Pulse ON time (C)	2	0.180173	0.090087	15.96	0.000	29.31
Pulse OFF time (D)	2	0.082208	0.041104	7.28	0.005	13.37
Residual error	18	0.101581	0.005643			
Total	26	0.614627				

Table 7: ANOVA results for MRR

Symbol	Process parameter	Level 1	Level 2	Level 3	max-min
A	Electrode material	-16.43	-12.86	-14.31	3.57
B	Pulse current (A)	-15.87	-15.06	-12.67	3.20
C	Pulse ON time (µs)	-12.78	-14.07	-16.75	3.97
D	Pulse OFF time (µs)	-15.02	-13.98	-14.60	1.05

Table 8: S/N ratios table for SR

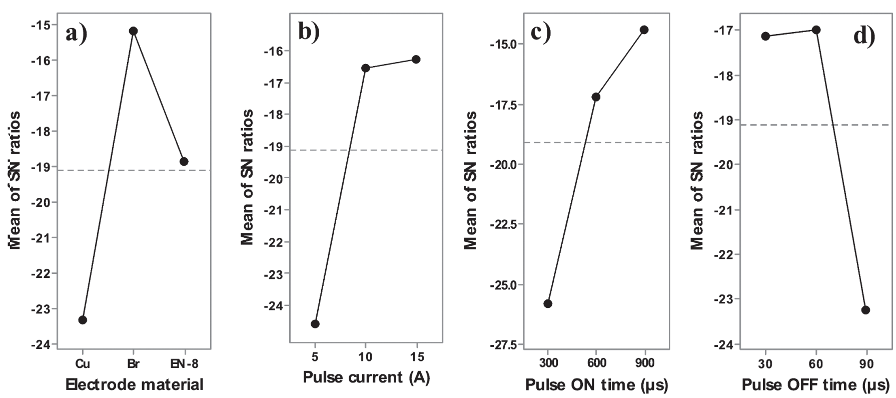


Figure 2: Main effect plot of S/N ratios for MRR a) electrode material, b) pulse current, c) pulse ON time, d) pulse OFF time

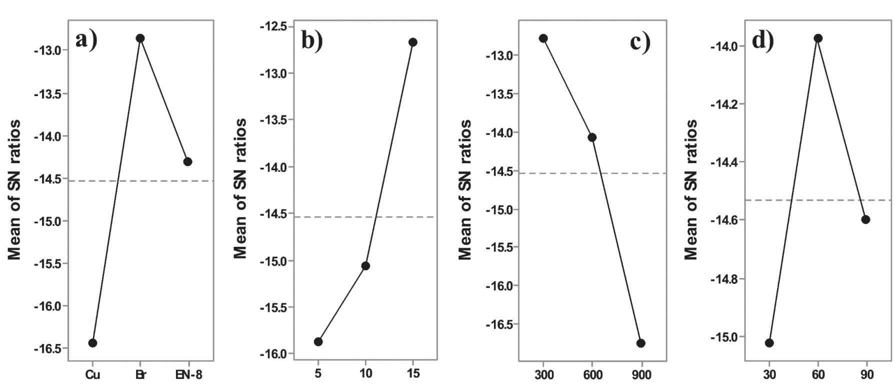


Figure 3: Main effect plot of S/N ratios for SR a) electrode material, b) pulse current, c) pulse ON time, d) pulse OFF time

Source	DF	Adj SS	Adj MS	F-ratio	P-value	P (%)
Electrode material(A)	2	25.379	12.689	12.85	0.000	25.62
Pulse current (B)	2	21.160	10.580	10.72	0.001	21.36
Pulse ON time (C)	2	32.242	16.121	16.33	0.000	32.56
Pulse OFF time (D)	2	2.469	1.234	1.25	0.310	2.49
Residual error	18	17.773	0.987			
Total	26	99.021				

Table 9: ANOVA results for SR

Symbol	Process parameter	Level 1	Level 2	Level 3	max-min
A	Electrode material	-30.69	-30.74	-27.31	3.42
B	Pulse current (A)	-31.59	-28.76	-28.40	3.19
C	Pulse ON time (µs)	-32.11	-28.94	-27.68	4.43
D	Pulse OFF time (µs)	-29.10	-28.47	-31.17	2.70

Table 10: S/N ratios table for EWR

OFF time (60 µs). Table 9 shows the results of ANOVA and the contribution of each individual parameter on the SR. It is also evident that pulse ON time is considered for the most significant parameter with a contribution of 32.56 % followed by the electrode material at 25.62 % and the pulse current at 21.36 %. Pulse OFF time is an insignificant parameter with a contribution of 2.49 %. Similar results have reported that pulse on time is the most important factor, affecting the SR during the machining of titanium grade 5 alloys [16]. The reason being: a higher pulse ON time reduces the SR when sufficient time is available between two sparks and when the dielectric fluid has cleaned the machined surface, resulting in a better surface finish.

Effect of machining parameters on the EWR. Figures 4a to 4d show the main effect plot of the process parameters, such as electrode material, pulse current, pulse ON time and pulse OFF time on the EWR. It can be seen that by increasing the pulse current and pulse ON time, the EWR increases. When pulse ON time increases, the high spark energy transferred to the machined surface, resulting in more heat produced between the electrode and the work piece and thus causing an increase in the electrode wear ratio. The mean S/N ratio for EWR is provided in Table 10. Pulse ON time is the most significant parameter affecting the EWR, followed by the electrode material, pulse current and pulse OFF time. A minimum EWR is obtained for the combination of process parameters ($A_3B_3C_3D_2$) which is to say, electrode material (EN-8), pulse current (15 A), pulse ON time (900 µs) and pulse OFF time (60 µs). The results of ANOVA for the EWR are given in Table 11. It has also been confirmed that pulse ON time is the most significant parameter, contributing 35.02 %, followed by the electrode material at 19.99 %, the pulse current at 15.23 % and pulse OFF time at 13.10 %. An increase in pulse current and pulse ON time increases the MRR, thus increasing the EWR due to increased erosion in the materials. These results are very similar to those of Narender Singh et al. who reported on a Al-10 wt.-% SiC metal matrix composite during EDM machining [6].

Contour plot analysis. Figures 5a to 5c show contour plots for the MRR with re-

Table 11: ANOVA results for EWR

Source	DF	Adj SS	Adj MS	F-ratio	P-value	P (%)
Electrode material(A)	2	656.73	328.36	11.50	0.001	19.99
Pulse current (B)	2	500.54	250.27	8.77	0.002	15.23
Pulse ON time (C)	2	1150.38	575.19	20.15	0.000	35.02
Pulse OFF time (D)	2	463.20	231.60	8.11	0.003	14.10
Residual error	18	513.85	28.55			
Total	26	3284.70				

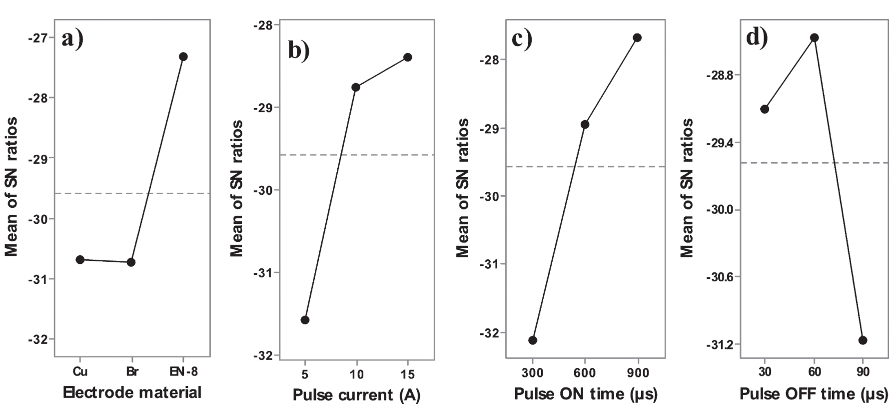


Figure 4: Main effect plot of S/N ratios for EWR a) electrode material, b) pulse current, c) pulse ON time, d) pulse OFF time

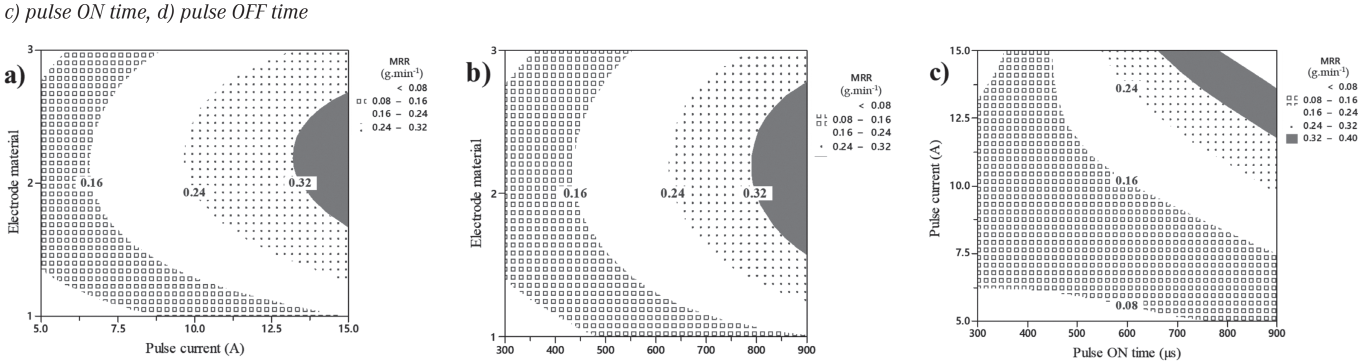


Figure 5: Contour plots for MRR, a) electrode material vs. pulse current, b) electrode material vs. pulse ON time, c) pulse current vs. pulse ON time

spect to variable input process parameters. For Figure 5a, 1 represents Cu, 2 represents Br, and 3 represents EN-8. Figure 5a shows the response of the electrode material and pulse current on the MRR. The dark area indicates the maximum MRR with respect to the electrode material and pulse current. It clearly shows that the Br electrode yields a higher MRR for a high pulse current. The Cu and EN-8 electrode yields a moderate level MRR with an increase in pulse current. Figure 5b represents the response of the electrode material and pulse ON time with respect to the MRR. In Figure 5b, the dark area shows the optimum level of the MRR. It can be observed that the Br electrode produces a maximum MRR for the higher pulse ON time. Figure 5c shows the response of the pulse current and pulse ON time with respect to the MRR. It can be seen that higher values of pulse current and pulse ON time are required to remove more materials in the work piece.

Figures 6a to 6c show the contour plots of the SR with respect to various input parameters. Figure 6a presents the response of SR with respect to the electrode material vs. the pulse current. The minimum SR is achieved for the Br electrode at a higher pulse current. The Cu electrode produces a greater SR at a low pulse current. Figure 6b shows the response of the electrode material vs. pulse ON time on the SR. It can be seen that the Br electrode yields a minimum SR when the pulse ON time is low, whereas, the EN-8 electrode yields a moderate SR. Figure 6c shows the response of pulse current vs. pulse ON time on the SR. It can be seen in the graph that a low pulse ON time and a high pulse current are preferred to achieve a good surface finish.

The contour plots for the EWR are presented in Figures 7a to 7c. In Figure 7a the response of the electrode material and pulse current on the EWR can be seen. In the graph, the minimum EWR obtained at the EN-8 electrode at a moderate pulse current can be observed. By contrast, both the Cu and Br electrodes have a maximum EWR with respect to pulse current. Figure 7b shows the response of the electrode material and pulse ON time on the EWR. It can be seen that with an increase in pulse ON time the EWR decreases. The thermal conductivity of the EN-8 electrode is low, resulting in a lower EWR. For these reasons, the accumulation of heat in the electrode is lower. Figure 7c presents the response of the EWR with respect to pulse current vs. pulse ON time. It can be seen in the graph that the EWR decreases with an increase in pulse current and pulse ON time. When the pulse ON time is low and the pulse current high, the EWR is high.

Interaction plot analysis. Figures 8a to 8c show the interaction plots for the MRR, SR and EWR. The interaction between electrode material, pulse current, pulse ON time and pulse OFF time with MRR is provided in Figure 8a. From the graph it can be seen that the electrode material and pulse current increase increases the MRR for electrode materials such as Cu, Br and EN-8. However, among the three electrode materials tested, the Br electrode removed the most materials from the work piece. The maximum MRR was observed in the Br electrode when the same pulse current level was applied. This is because of the low electrical conductivity nature of brass ($159\ W \times (mK^{-1})$) which does not absorb heat, meaning all the heat generated for melting and for the vaporization of work materials. When pulse ON time and pulse current interact, the increase of both factors increases the MRR and pulse ON time plays a significant role in affecting the MRR. This occurs because an increase in pulse ON time maintains a continuous discharge of heat energy melting the material to a larger extent. The interaction of pulse ON time with pulse OFF time clearly displays this. Pulse OFF time does not contribute to the MRR at any point. When the electrode material interacts with pulse ON time, a very similar trend is observed as in the interaction of the electrode material and the pulse current. The interaction between the electrode material and the pulse current with pulse OFF time reveals that pulse OFF time is an insignificant factor for the MRR.

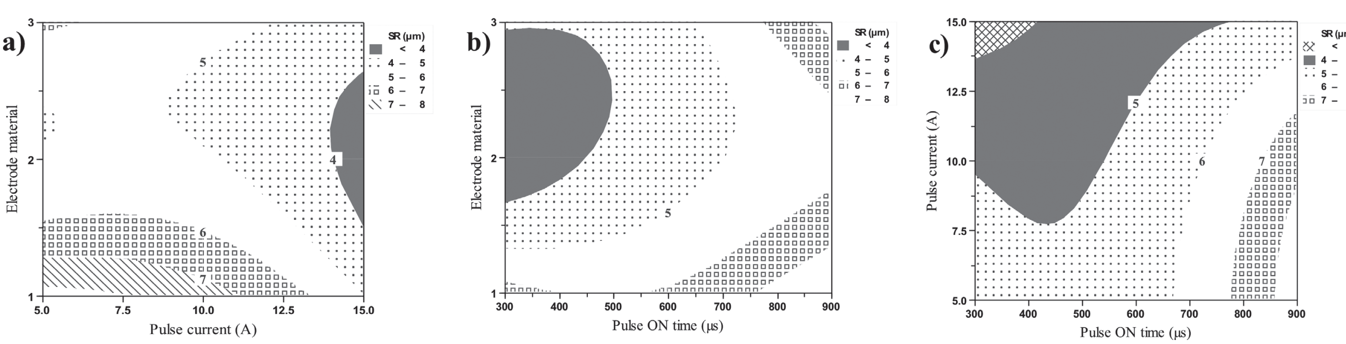


Figure 6: Contour plots for SR, a) electrode material vs. pulse current, b) electrode material vs. pulse ON time, c) pulse current vs. pulse ON time

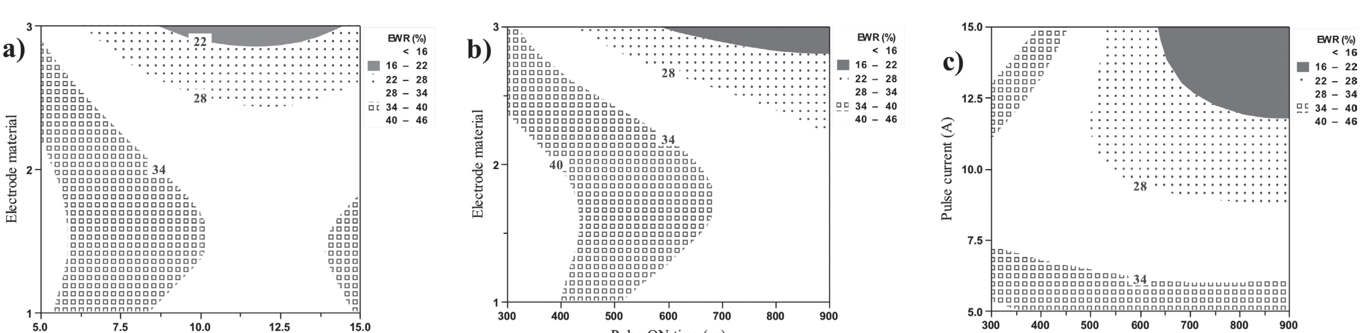
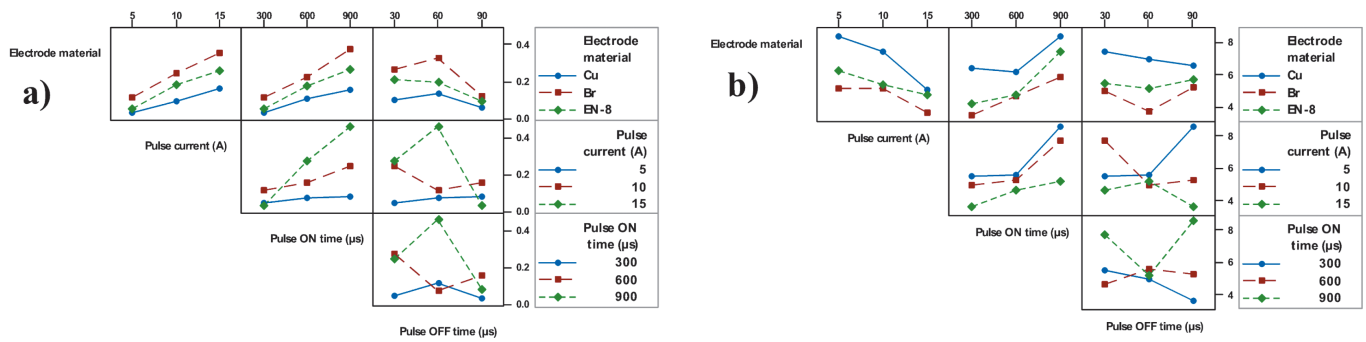


Figure 7: Contour plots for EWR, a) electrode material vs. pulse current, b) electrode material vs. pulse ON time, c) pulse current vs. pulse ON time



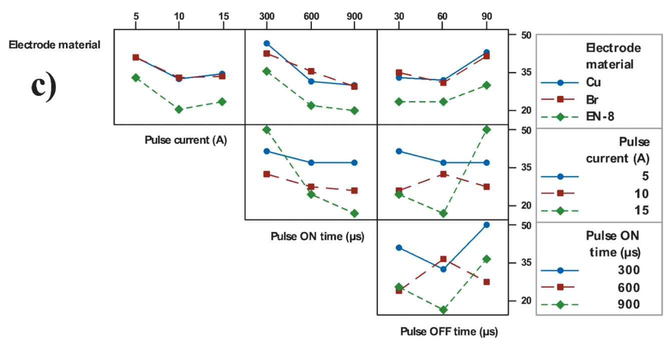


Figure 8: Interaction plot a) MRR, b) SR, c) EWR

Figure 8b shows an interaction plot for the SR. The interaction between the electrode material and the pulse current confirms the fact that an increase in pulse current affects the SR. Better surface finish was observed for the Br electrode. When pulse current and pulse ON time interact, an increase in both parameters increases the SR. The interaction between the electrode material and pulse ON time and pulse OFF time shows that Br is the most suitable electrode material for the EDM of an AA7075-10 wt.-% TiO_2 composite. An Interaction between pulse OFF time with all other factors shows that pulse OFF time is an insignificant factor for the SR. The interaction plot for the EWR is provided in Figure 8c. The plot shows that when the electrode material interacts with the pulse current, the pulse ON time and pulse OFF time, EN-8 is the best electrode material for a moderate level of pulse current, high pulse ON time, and low pulse OFF time. The low EWR is observed in the above mentioned parameters. The interaction between the pulse current and pulse ON time shows that a lower pulse current and a high pulse ON time is the ideal condition for decreasing the EWR. As discussed in previous sections, the pulse OFF time is an insignificant factor in affecting the EWR during the EDM of AA7075-10 wt.-% TiO_2 composite.

Conclusions

The following conclusions can be drawn from above results:

1. AA7075-10 wt.-% TiO_2 composite can be fabricated successfully through stir casting. EDM machinability was studied.
2. Taguchi based S/N ratio was used to identify an optimum combination of the process parameters on EDM machining with the objectives of maximizing the MRR and minimizing the SR and EWR.
3. The optimal parameters for the maximization of the MRR depends on the electrode material: Br, pulse current: 15 A, pulse ON time: 900 µs and pulse OFF time: 60 µs.
4. The optimal parameters for miniming the SR depend on the electrode material: Br, pulse current: 15 A, pulse ON time: 300 µs and pulse OFF time: 60 µs.
5. The optimal parameters for minimizing the EWR: electrode material: EN-8, pulse current: 15 A, pulse ON time: 900 µs and pulse OFF time: 60 µs.
6. The experimental results found that pulse ON time and pulse current are the most significant factors for the MRR while pulse ON time and electrode material are the most important for the SR and EWR.

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