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Influence of Process Parameters in EDM Machining of Aluminium Titanium Carbide Composite

Dr.S.SyathAbuthakeer[1], S.Mohith Kaameswaran[2], K.Venkatachalam[3], M.Vishhnuram[4]

[1] Associate Professor, Department of Mechanical engineering,
PSG College of Technology,Peelamedu, Coimbatore, India - 641004.
[2]Department of Mechanical engineering,
PSG College of Technology, Peelamedu, Coimbatore, India - 641004.
[3]Department of Mechanical engineering,
PSG College of Technology, Peelamedu, Coimbatore, India - 641004.
[4]Department of Mechanical engineering,
PSG College of Technology, Peelamedu, Coimbatore, India - 641004.

Abstract: Electric Discharge Machining (EDM) is a non-conventional precision machining technique that allow extremely hard materials to be machined with relative ease. With the advent of composites, the use of EDM has garnered popularity and widespread attention. With modern composites, various naturally non-coexisting combination of properties have now been made feasible. In this paper, the Electric Discharge Machining of Aluminium Titanium Carbide Composite has been investigated. The influence of the process parameters like Peak Current, Pulse ON time, Pulse OFF time and Servo Voltage on the Material Removal Rate (MRR) and Surface Roughness of the process has been studied. The Design of experiments was carried out using the robust Taguchi Orthogonal Array Approach. The significance of the process parameters on the process characteristics were analysed statistically using ANOVA.

Keywords: EDM, Process parameter Influence, Aluminium Titanium Carbide, Taguchi.

I. Introduction

EDM machining is done electrically by inducing repetitive and controlled sparks of high energy bursts between the workpiece material and the tool electrode. When an appropriate voltage is applied between the tool and workpiece separated by a specified distance, an electric field builds up. When the applied potential exceed the breakdown potential of the dielectric, ionisation takes place. A high current flow resulting in a spark which consequently removes the metal by partially melting and partially vaporising it. This discharge takes place at the point of smallest separation where the resistance is least. Progressively these sparks produce cavities on the surface of the workpiece resulting in the formation of a contour complementary to that of the tool. The experimental setup of a general EDM machine is given in Fig.1.

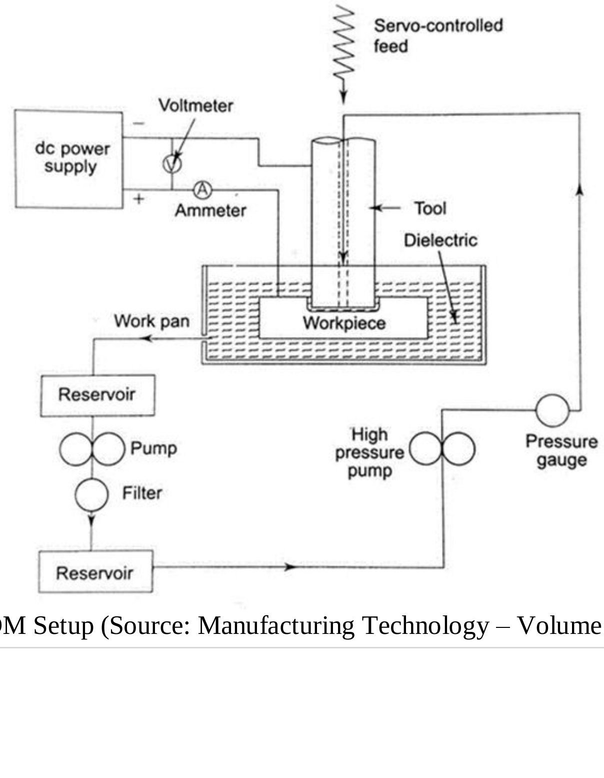

Fig.1 Basic EDM Setup (Source: Manufacturing Technology – Volume II by P N Rao)

The dielectric fluid flushes out the debris consisting of tiny metal globules from the machining spot. The EDM process is highly efficient for the machining of hard metals since the hardness of the workpiece has little effect on the process.

Proper process parameter selection is essential to improve productivity and efficiency of EDM process. M P Jahan et al. looked into the effects of electrical process parameters in EDM process using an RC pulse generator while machining tungsten carbide workpiece with brass tool electrode [1]. Ayesta et al. has tested the influence of electric discharge current and pulse ON time, material removal rate and tool wear rate of EDM process while machining the C1023 Aeronautic alloy with POCO tool electrode [2]. They concluded that electrode wear reduces when the input current and surface roughness increases. Durairaj et al .analysed the process parameter of wire EDM with stainless steel using Taguchi method and Grey relational Grade [3]. They deduced that pulse ON time plays major role on surface roughness and kerf width. They used ANOVA for study of the parameter relationships. Vikas et al. analyzed the effect of process parameters on the surface roughness in EDM for EN41 materials using Grey-Taguchi method [4]. They found that the discharge current has a larger impact over the surface roughness. The effect of other process parameters are significantly less and ignored. Feng Yerui et al. investigated the EDM parameters for TiC/Ni Cermet machining [5]. They concluded that pulse ON time increases the material removal rate and increase the surface roughness. Gasification and melting are the main material removal methods observed. SEM images were used for the surface analysis.Ravindranandh Bobbili et al.analyzed the multi response optimization of wire EDM process parameters of ballistic grade aluminium alloy [6].

Modern materials like Metal Matrix Composites popularly known as MMCs have gave gained spot in this field. Metal Matrix Composites are composed of hard brittle ceramic particles dispersed in a ductile medium. Aluminum has excellent ductility, machinability, conductivity etc. Titanium carbide on the other hand, is one of the hardest engineering material. But it has poor machinability and conductivity. The particulate composite of these two materials provides a desirable blend of the properties of the two materials. Al-TiC has excellent resistance to wear, creep and fatigue, and also good stiffness and strength-to weight ratio. They find application as structural materials for aerospace and automobile industries. Hence in this paper the EDM machining characteristics Aluminium - Titanium Carbide composite (Al-TiC) has been studied.

II. Specimen Preparation

Malek Ali et al. have studied the properties of aluminium reinforced with various ratios of TiC particles. The hardness was found to increase with the percentage of TiC particles added and the wear rate was found to decrease with the percentage of TiC particles added. The electrical conductivity was found to decrease with increasing amounts of TiC [7]. The microstructure and mechanical properties of Al-TiC composite of various compositions were analysed by SangitaMohapatra et al. [8] Low density TiC reinforcement was found to significantly increase the mechanical properties of the composite.V.Ramakoteswara Rao et al. have studied the tribological properties of aluminium metal matrix composites reinforced with TiCparticles [9]. Based on extensive literature survey, Al-TiC composite with 5% TiC reinforcement was chosen for the study. This is because there is no significant increase in hardness at higher percentage ratios of Al-TiC due to agglomeration and casting defects. Bars of aluminium 6063 and 5% TiC particles (by weight) in powdered form were stir casted to obtain the specimens for test.

Fig.2 Stir Casting Setup

The composite was prepared by stir casting process. The apparatus used is shown in the Fig.2. The Stir casting apparatus consisted of an electrical furnace with a stirrer powered by a motor and a provision for the preheating and adding of the particulate reinforcement. The pouring temperature of Aluminium was about 720^{o}C. The preheat temperature of the titanium carbide powder was set to 300^{o}C. After the complete melting of the metal, the stirrer was turned on and the addition of the particulate reinforcement began, thereby ensuring a homogeneous mixture. The molten metal in the furnace (shown in Fig.3) was then poured into a die for curing. The Cast piece was turned to 33mm diameter and cut into pieces of 25mm length.

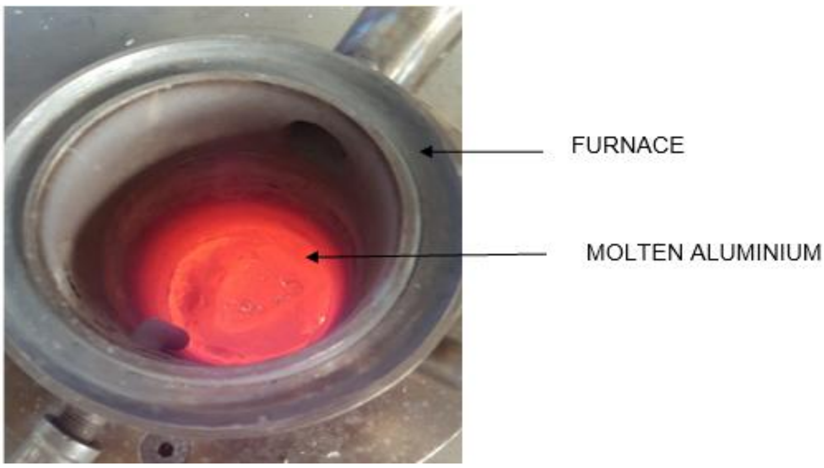

Fig.3 Molten Aluminium in the furnace

III. Experimental Setup

The EDM machining was carried out in the Mitsubishi EA8 EDM machine (Fig. 4) available at the Centre for Advanced Toolingand Precision Dies machine in PSG College of Technology.

Fig.4 Mitsubishi EA8 EDM machine

3.1 Equipment and Procedure

The dielectric fluid used for machining was Daphne Cut HL-35. The flushing technique used was simple jet flushing. Two jets were directed at the machining spot for debris removal as shown in the Fig.5.The Al-TiC test specimen was clamped using a vice fitted to the magnetic table of the machine.

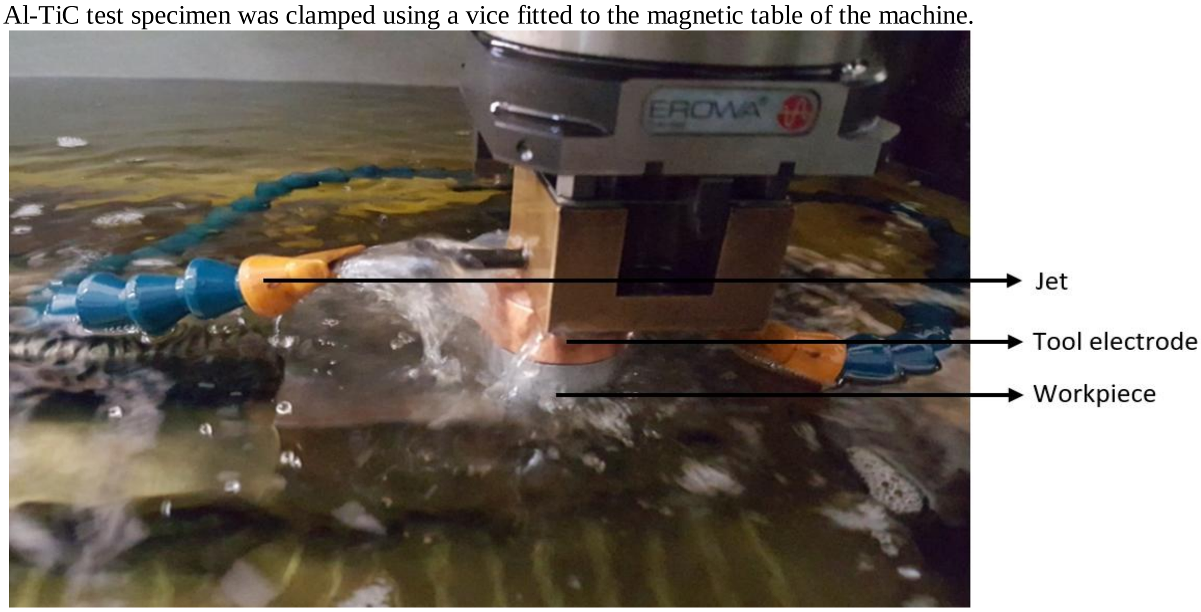

Fig.5 Experimental Setup

The copper electrode was machined from a copper rod to a diameter of 35mm using a lathe as shown in Fig.6. The bottom surface of the electrode which removes the metal was polished using diamond paste to get a good surface finish.

Fig.6 Copper Electrode used for machining

Each of the test specimen was machined using the above electrode for a fixed time of 15 minutes. The Material Removal Rate was calculated from the mass of the material removed during this time interval. The mass of the material removed was found by noting the weight of each workpiece before and after machining using an electronic weighing scale.

$$MRR = \frac{Initial\ Weight - Final\ Weight}{Machining\ Time} \qquad (1)$$

During machining it was observed that there occurred a deposition of the debris on the electrode at a high rate. The surface roughness was measured using Kosaka 1200 Surface Roughness Tester. This machine is capable of measuring various surface roughness tester like Ra, Rz, Rt etc. The Ra value has been used for this study. The probe of the tester was fashioned out of diamond.The cut off length was set to 2.5mm. The measurements were taken in both the longitudinal and transverse direction and the average value was taken as the mean Surface roughness.

3.2 Design of Experiment

The design of experiments has been carried out using Taguchi technique. The L9 orthogonal array four parameters with three levels each has been used. The parameters under study are Peak current, Pulse ON time, Pulse OFF time and Servo Voltage

Table.1 Process Parameter and their Levels

Parameter	Unit	Level 1	Level 2	Level 3
Peak Current	amperes	8	12	15
Pulse ON Time	microseconds	64	102.4	140
Pulse OFF Time	microseconds	32	102.4	204
Servo Voltage	volts	0	1	-1

For each combination of the parameters as per the L9 array, two trials were conducted. The mean of the values obtained from the two trial was used for analysis. Signal-to-noise ratio (S/N Ratio) is a parameter that compares the level of a desired signal to the level of background noise. There are two formulae used to calculate S/N Ratio [10].

For parameters of higher the better type like Material Removal Rate (MRR),

$$S/N_{\mathrm{MRR}} = -10 \log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \qquad (2)$$

For parameters of lower the better type like Surface Roughness,

$$S/N_{\mathrm{SR}} = -10 \log_{10}\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right] \qquad (3)$$

The results of the experiment are shown in the table below. The results have been further analysed using the software Minitab 17.0.

Table.2 L9 Experimental Design

Trial No	Peak Current (A)	Pulse ON Time (µs)	Pulse OFF Time (µs)	Servo Voltage (V)	MRR (g/min)	Surface Roughness (µm)
1	8	64	32	0	0.037413333	3.49
2	8	102.4	102.4	1	0.021413333	2.91
3	8	140	204	-1	0.013013333	4.494
4	12	64	102.4	-1	0.022426667	8.649
5	12	102.4	204	0	0.022333333	7.033
6	12	140	32	1	0.077053333	10.113
7	15	64	204	1	0.011526667	15.515
8	15	102.4	32	-1	0.134293333	8.853
9	15	140	102.4	0	0.080453333	12.351

IV. Results and Discussions

The results obtained from the experimentation were analysed using Minitab 17. The Fig.7 and Fig.8 show the mean effect plot for the SN ratios of MRR and Surface Roughness respectively. From the graphs, it can be understood that the MRR varies widely with peak current and pulse OFF time and the surface roughness is most influenced by the peak current of the process.

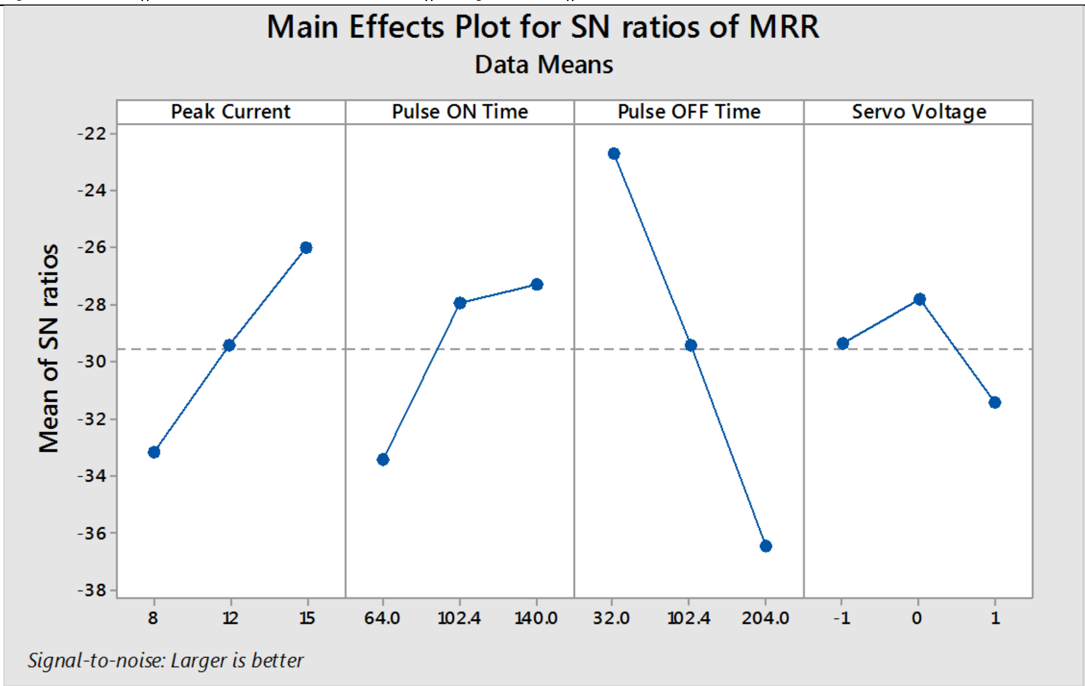

Fig.7 Mean Effect plot for SN ratio of MRR

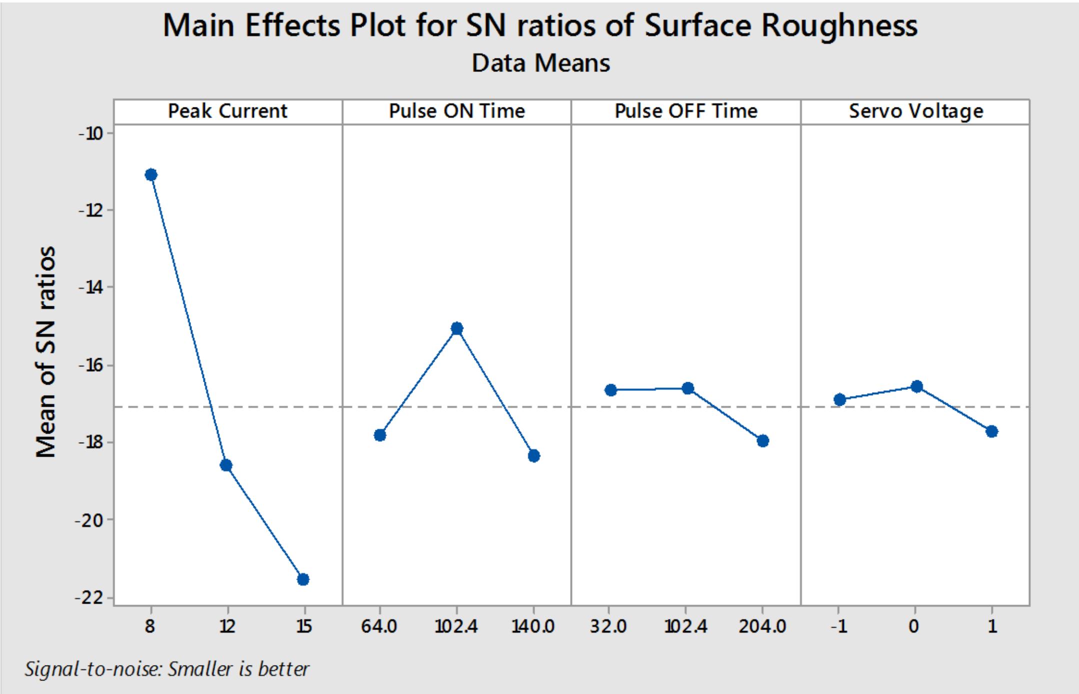

Fig.8 Mean Effect plot for SN ratio of Surface Roughness

It can be seen that peak current has an almost linear relationship with both MRR and surface roughness. The servo voltage is found to have least influence on both the MRR and surface roughness. The following two graphs show the variation of MRR and surface roughness with their two most significant parameters.

The Fig.9 shows that peak values of MRR are obtained at lower values of pulse OFF time and high values of peak current. Whereas it can be inferred from Fig.10 that lower values of peak current and pulse ON time tend to provide a better surface finish.

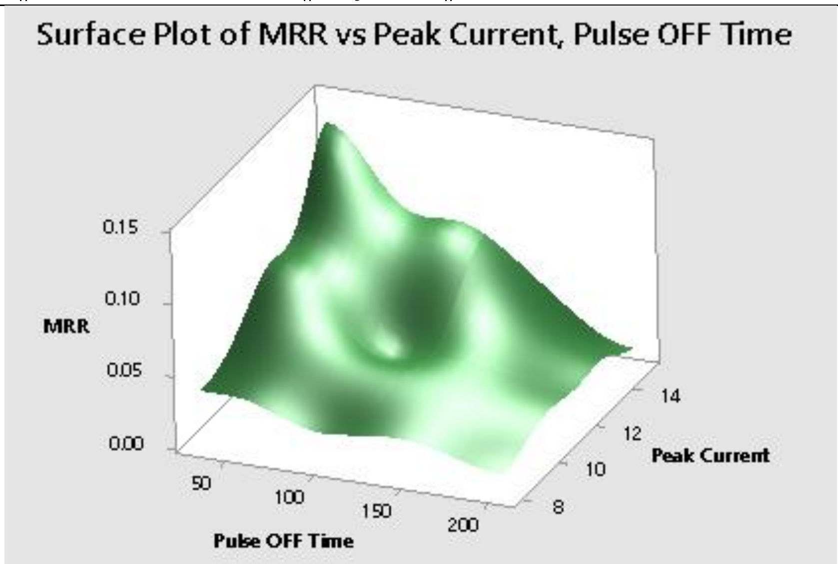

Fig.9 MRR vs Peak Current and Pulse OFF time

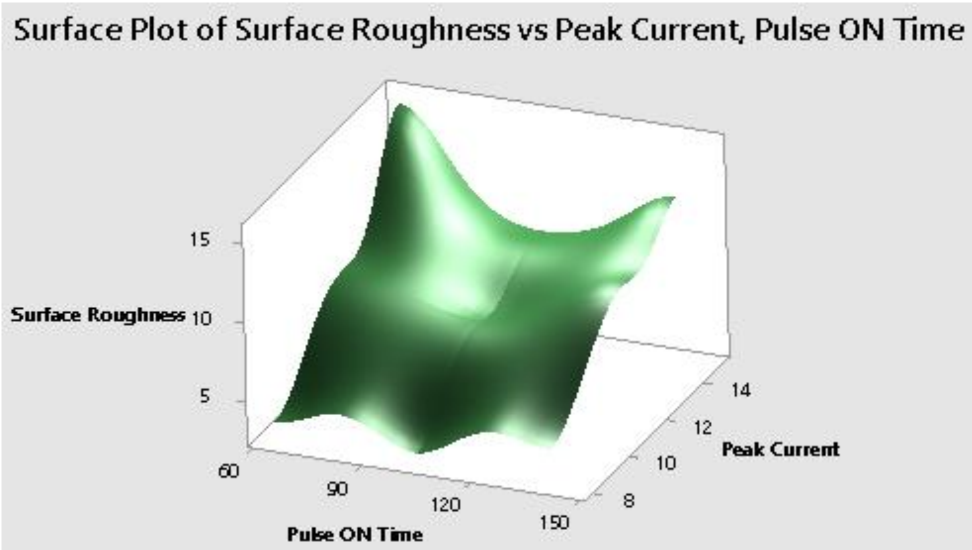

Fig.10 Surface Roughness vs Peak Current and Pulse ON time

Analysis of Variance (ANOVA) is a statistical technique used to determine if the variations in the results obtained are of any statistical significance. Higher the value of F-ratio, higher is the statistical influence of the parameter on the process output. The ANOVA test carried out for the MRR and surface roughness with a confidence level of 90% is shown in the Table.3 and Table.4 respectively.

Table.3 ANOVA- MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Peak Current	2	0.004140	0.002070	6.96	0.126
Pulse ON Time	2	0.002363	0.001182	3.97	0.201
Pulse OFF Time	2	0.006916	0.003458	11.63	0.079
Error	2	0.000595	0.000297		
Total	8	0.014014			

Table.4 ANOVA- Surface Roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Peak Current	2	112.034	56.017	13.33	0.070
Pulse ON Time	2	16.174	8.087	1.92	0.342
Pulse OFF Time	2	3.662	1.831	0.44	0.697
Error	2	8.406	4.203		
Total	8	140.275			

To declare that the variations due to a parameter to be statistically significant for a confidence level of 10%, the P-Value should be less than 0.1. Hence from the above results, the Pulse OFF time is the most statistically significant parameter for MRR (since 0.079 is less than 0.1) and the Peak current is the most statistically significant parameter for the surface roughness (since 0.070 is less than 0.1).

V. Conclusion

Thus the study has provided insight into the effects of Peak Current, Pulse ON Time, Pulse OFF time and Servo voltage on the MRR and surface roughness of Electric Discharge Machining of Aluminium Titanium Carbide composite. The Pulse OFF time and Peak current were found to have the most predominant influence on the MRR of the EDM process. The increasing values of peak current resulted in high values of surface roughness. This can be conceptually correlated high values of current translate to high values of energy discharged by the sparks resulting in the formation of craters of larger size. Thus the surface finish is deteriorated with high peak current. The results have also been statistically interpreted using Taguchi approach and ANOVA using Minitab 17.0.During the experiment, a black layer of debris was deposited on the copper electrode which hindered the material removal. The nature of the deposits and the reasons for deposition are yet to be investigated in future study

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