INVESTIGATION OF OPTIMUM PARAMETER OF ELECTRO-DISCHARGE MACHINING FOR TWO PHASE CARBON FIBER COMPOSITES USING TAGUCHI METHOD

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Abstract—
In this paper author investigate the optimum parameter of Electric discharge Machining (EDM) for two phase carbon fiber composite. Taguchi method was used for optimization of process parameter. Author was used copper-cadmium tool for machining of two phase carbon fiber composite. Four major control factors named as peak current (Ip), gap voltage (Vg), pulse-on-time (Ton) and duty cycle (η) are considered to determine the effect on Tool Wear Rate (TWR) and Material Removal Rate (MRR). In Taguchi technique for design of experiment three levels of each parameter has been taken into consideration by using standard L9 orthogonal array.

Index Terms— EDM, Taguchi method, MRR, TWR

I. INTRODUCTION

EDM is the thermal erosion process in which metal is removed by a series of recurring electrical discharges between a cutting tool acting as an electrode and a conductive workpiece, in the presence of a dielectric fluid. This discharge occurs in a voltage gap between the electrode and workpiece. Heat from the discharge vaporizes minute particles of workpiece material, which are then washed from the gap by the continuously flushing dielectric fluid. Electrical discharge machining is a machining method primarily used for hard metals or those that would be very difficult to machine with traditional techniques. EDM typically works with materials that are electrically conductive, although methods for machining insulating ceramics with EDM have also been proposed. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them. This method can be used with any other metal or metal alloy such as titanium, hastelloy, kovar, and Inconel. Morgan et. al. (2004) used this process to shape polycrystalline diamond tools have been reported. Cogun, Akasalan, and Kaftanoglu (2002) proposed attainment of accurate and consistent EDM performance are mainly dependent on eight main factors; polarity, open-circuit, discharge current, pulse duration, electrode material, pulse interval, gap control and circulation rate. Yilmaz et. al. (2006) proposed that the first four of these are called planning parameters that are dependent on the type of machining operation and whether the cut is roughing or finishing operation. The last four are adjusted to give the best operating conditions for the machine used and result required. Tzeng and Chen (2007) proposed that the operating parameters of the EDM process are mainly set based on the trial and error experience of the operator. Ross (1996) proposed that Taguchi suggests a procedure that applies orthogonal arrays from statistical design of experiments to efficiently obtain the best model with the least number of experiments.

From the above study it is concluded that there are number of techniques used for optimization of process parameters. But in this paper we developed a Taguchi-Fuzzy based approach for optimization of process parameters.

2. Plan of experiment

In the present study L9 standard orthogonal array has been used which is attributed to its suitability for 3 level problems. On the basis of Taguchi method four factors with three levels of each are selected and, the L9 array has been made for calculating the MRR and TWR. From the range of acceptable values of various selected factors we have been selected the following suitable level values of various factors.

Table 1:-EDM process parameters and their levels

Machining Parameters		Level 1	Level 2	Level 3
A	Ip	1	3	5
B	Vg	20	40	60
C	Ton	60	80	100
D	η	0.4	0.5	0.6

3. Experimental Details and design

The machining of carbon fiber (CF) epoxy composite has been performed on Super cut 3822 model Electronica. The composite has high strength to weight ratio with military and aerospace application. This EDM machine has peak current range (1-20 ampere), gap voltage range (10-60 volts), pulse duration range (0.2-500 μ-seconds). The dielectric fluid used in this study is kerosene.

The work piece material used in the experiment is 'carbon fiber' which has a very high strength to weight ratio. The properties of carbon fiber are as follows: Resin LY556 (Phenolic) Hardener 154 DDS, Epoxy 427 gm. Ethyl Methyl Ketone, Size of 30×20(mm × mm).

The material used for the tool in the experiment is 'Cu-Cd (copper-cadmium)' and widely used in industries for the tooling of EDM.

The same experimental procedure has been repeated 9 times with different tool and work piece. The appropriate setting has also been done by various selected parameters decided by DOE.

Table 2: L9 array table for DOE based on Taguchi method

EXPERIMENTAL NO.	Ip	Vg	Ton	η
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	2	3
9	3	3	1	1

4. Performance measure procedure

During experiments, material removal occurs in both work pieces as well as in tool. The weight loss has been calculated by weighing the samples before and after performing the machining. Two processes MRR and TWR are used to decide the machining efficiency, which can be described as follows:

$$MRR = \frac{\text{Weight reduction on work piece during machining}}{\text{Time taken in machining}}$$

$$TWR = \frac{\text{Weight reduction on tool during machining}}{\text{Time taken in machining}}$$

5. Experimental results and discussion

Table 3 & 4 shows the entire experimental results about the MRR and TWR at different experiment number. The values of MRR are found to be between 0.000558 and 0.002152 gm.

/minute and the value of TWR are found to be between 0.000026 and 0.000358 gm. /minute.

Table 3: MRR for various experiments

Exp. No.	Weight before m/c (in gm.)	Weight after m/c (in gm.)	Material removed (in gm.)	Time of exp. (in min.)	MRR (in gm./min.)
1	5.6772	5.6102	0.0670	60	0.000558
2	6.6458	6.5808	0.0650	112	0.000580
3	6.5439	6.4789	0.0604	98	0.000616
4	7.1173	7.0523	0.0650	105	0.000619
5	5.9945	5.9342	0.0603	85	0.000709
6	6.1348	6.0714	0.0634	78	0.000812
7	6.0145	5.958	0.0565	54	0.001046
8	5.4759	5.4173	0.0586	46.3	0.001265
9	5.5779	5.5047	0.0732	34	0.002152

Table 4: TWR for various experiments

Exp. No.	Weight before m/c (in gm.)	Weight after m/c (in gm.)	Material Removed (in gm.)	Time of exp. (in min.)	TWR (in gm./min.)
1	12.0467	12.0412	0.0055	60	0.000045
2	12.0986	12.0956	0.0030	112	0.000026
3	12.1045	12.0996	0.0049	98	0.000050
4	12.1067	12.1012	0.0055	105	0.000052
5	11.9864	11.9814	0.0050	85	0.000058
6	11.9969	11.9909	0.0060	78	0.000076
7	12.1382	12.1298	0.0084	54	0.000155
8	12.1416	12.1302	0.0114	46.3	0.000246
9	12.0853	12.0731	0.0122	34	0.000358

Table 5:- S/N ratio for MRR and TWR

Exp. No.	I_p	V_g	T_{on}	η	MRR(S/N)	TWR(S/N)
1	1	20	60	0.4	-65.06	86.93
2	1	40	80	0.5	-64.73	91.70
3	1	60	100	0.6	-64.20	86.02
4	3	20	80	0.6	-64.16	85.67
5	3	40	100	0.4	-62.98	84.73
6	3	60	60	0.5	-61.80	82.38
7	5	20	100	0.5	-59.60	76.19
8	5	40	60	0.6	-57.95	72.18
9	5	60	80	0.4	-53.34	68.92

6. Response effect for Signal-to-noise ratios of MRR and TW

Table 6 and Table 7 shows the response effect for signal-to-noise ratio of MRR and TWR for each level of parameters.

Table 6: Response effect for Signal-to-noise ratio of MRR

Level	I_p	V_g	T_{on}	η
1	-64.66	-62.94	-61.60	-60.46
2	-62.98	-61.88	-60.74	-62.04
3	-56.96	-59.78	-62.26	-62.10
Max-Min	7.70	3.16	1.52	1.64
Rank	1	2	4	3

Table 7: Response effect for Signal-to-noise ratio of TWR

Level	I_p	V_g	T_{on}	η
1	88.21	82.93	80.49	80.19
2	84.26	82.87	82.09	83.42
3	72.43	79.10	82.31	81.29
Max-Min	15.78	3.83	1.82	3.23
Rank	1	2	4	3

A greater value of S/N ratio is always considered for better performance irrespective of the category of the performance characterisrics.

The difference of maximum and minimum mean S/N ratio indicates the significance of the process parameters, greater the difference, greater will be the significance.

Table 6 and Table 7 both shows that the peak current (I_p) contributes most significantly towards MRR and TWR as the difference value is highest, followed by gap voltage (V_g), duty cycle (η) and pulse on time (T_{on}).

7. Conclusion

The experiment results confirm the prior design and analysis for optimizing the EDM machining process parameters by using Taguchi method. This shows that the Taguchi method provides a systematic and efficient methodology for the parametric design with far less effort than would be required for most optimization techniques. Based on experimental results, following conclusion can be drawn:

(1) For 'Maximum MRR' and 'Minimum TWR', optimal combination of process parameters are$A_3B_3C_2D_1$ and $A_1B_1C_3D_2$ respectively.

(2) Peak current (I_p) contributes most significantly towards MRR and TWR as the difference value is highest, followed by gap voltage (V_g), duty cycle (η) and pulse on time (T_{on}

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