

Regression model for surface roughness on EDM using Al6061 + SiC, Copper and Brass Tools

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ABSTRACT

Keywords:

Discharge Current (I_p),
Pulse On Time (T_{ON}),
Pulse Off Time (T_{OFF}),
Surface Roughness,
EDM.

Electrical Discharge Machining (EDM) is one of the electrical energy based Modern Machining Technique. where electrical energy is directly used to remove or cut the metals. In the present work experiments are conducted on EDM using Al6061+SiC(3%,6%,9%), Copper and Brass materials as electrodes and EN8 steel as work material. Discharge current (I_p), pulse on time (T_{ON}), pulse off time (T_{OFF}) are selected as process parameters, Surface Roughness (S_R), Tool Wear Rate (TWR) as response. Taguchi design of experiment is used to find the influence of process parameters on response and a mathematical model is developed. Percentage contribution of each factor is determined.

1. Introduction

Electrical Discharge Machining (EDM) process involves a controlled erosion of electrically conductive materials by initiation of rapid and repetitive spark discharge between electrode tool and work piece, separated by a small gap of about 0.01 to 0.05mm known a spark gap. This is either flooded or immersed under dielectric fluid. The controlled pulsing of direct current produces the spark discharge between the work piece and tool. Each spark produces enough heat to melt and vaporize a tiny volume of the work piece material leaving a small crater on its surface. The energy contained in each spark is discrete and it can be controlled so that material removal rate, surface finish and tolerance can be produced. EDM is most widely used machining process among the non-traditional machining methods. Its chief applications are in the manufacture and reconditioning of press tools and forging dies as well as moulds for injection moulding. It is successfully employed for producing intricate and irregular shape profiles common in tool rooms.

2. Objectives & Methodology

A Mathematical model is developed to optimize

the input parameters for each tool used for machining by Design of Experiments. In design of experiments, numbers of trails to be conducted are determined by Taguchi DoE and design matrix is constructed for both Al6061 + SiC (3%,6% & 9%),Copper and Brass electrodes used. Experiments are carried out as per the design matrix. After getting the design matrix, regression coefficients are calculated. Adequacy of model is tested by fisher test at 5% significance level. Student's t-test is done for each regression coefficient to check the significance. The final mathematical model is formed after removing non significant coefficients. Finally Analysis of Variance (ANOVA) is done to find out the percentage contribution of each factor to the Surface Roughness.

Taguchi DoE

Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting minimal number of experiments which could give the full information of all the factors that affects the performance parameters. There are many standard orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels. For example, if one wants to conduct an experiment to understand the influence of

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4 different independent variables with each variable having 3 set values (level values), then an L9 orthogonal array might be the right choice. The L9 orthogonal array is meant for understanding the effect of 4 independent factors each having 3 factor level values. This array assumes that there is no interaction between any two factors. While in many cases, no interaction model assumption is valid, there are some cases where there is clear evidence of interaction. A typical case of interaction would be the interaction between the material properties and temperature.

Postulation of Mathematical Model

The regression equation is an algebraic representation of the regression line and describes the relationship between the response and predictor variables. The regression equation takes the form of:

Response = constant + coefficient * predictor + ... + coefficient * predictor
or $y = b_0 + b_1X_1 + b_2X_2 + \dots + b_kX_k$

Where:

- Response (Y) is the value of the response.
- Constant (b_0) is the value of the response variable when the predictor variable(s) is zero. The constant is also called the intercept because it determines where the regression line intercepts (meets) the Y-axis.
- Predictor(s) (X) is the value of the predictor variable(s). The predictor can be a polynomial term.
- Coefficients (b_1, b_2, \dots, b_k) represent the estimated change in mean response for each unit change in the predictor value. In other words, it is the change in Y that occurs when X increases by one unit.

Table 1
EDM Factors and Levels.

Process parameter	Units	Level 1	Level 2	Level 3
Pulse on time(T_{ON})	μs	200	500	900
Pulse off time(T_{OFF})	A	100	200	500
Voltage(V)	V	30	40	45
Current(I)	μs	6	8	10

The EDM process variables (factors) are identified to develop the mathematical model to predict the MRR and SR. These include pulse on time (T_{ON}), pulse off time (T_{OFF}) and pulse current (I_p), Voltage (V). The first order model is assumed with two and three four interactions which can be expressed as

Regression

Regression investigates and models the relationship between a response (Y) and Predictors (X). The response must be continuous, but you can have both continuous and categorical predictors. You can model both linear and polynomial relationships.

In particular, regression analysis is often used to determine how the response variable changes as a particular predictor variable change. Minitab stores the last regression model that you fit for each response variable. You can use stored models to quickly generate predictions, contour plots, surface plots, overlaid contour plots, and optimized responses. For analyses that can use multiple responses, you will need to fit a model for each response.

3. Experimentation

The experimentation is carried out on Electrical Discharge Machine which is classified as (die-sinking type) SYCNC PC-60 whose polarization on the electrode be located as negative whereas that of work piece be located as positive. The dielectric liquid recycled was EDM oil having specific gravity 0.763. (Ref. Fig. 1 & 2)

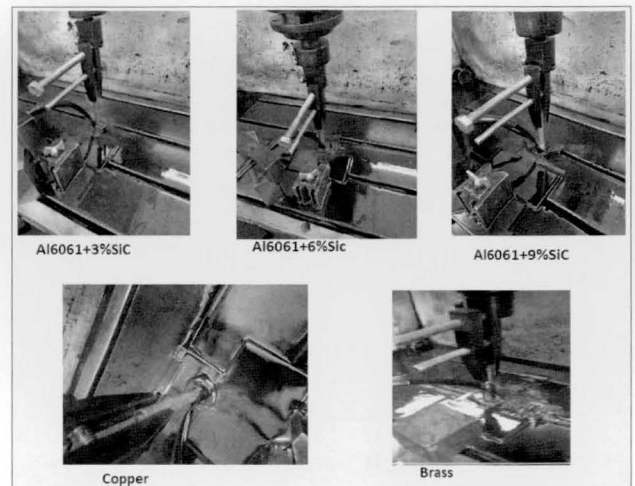


Fig. 1. Machining with different types of tools.

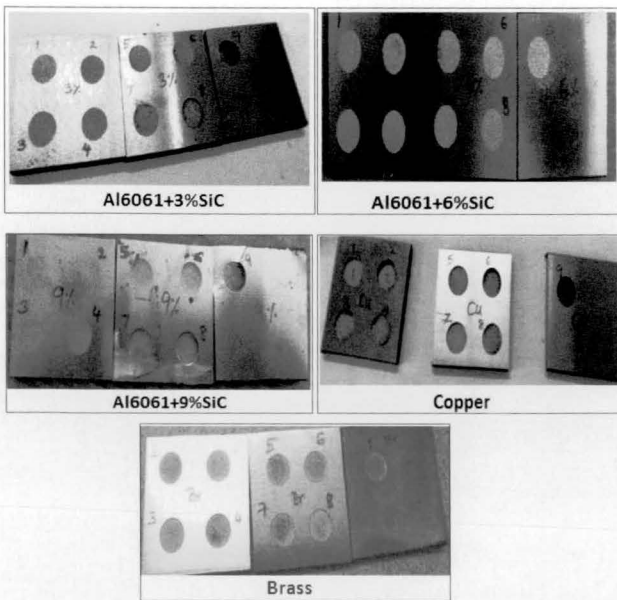


Fig. 2. Work pieces.

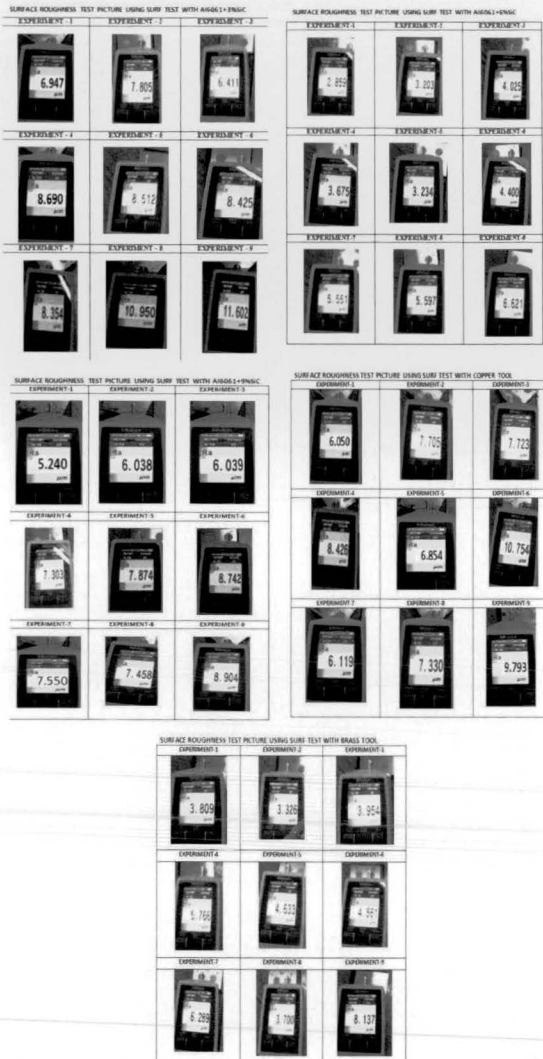


Fig. 3. Surface Roughness Test Pictures Using Surf Test.

Table 2

Calculated S_R for Al6061+SiC(3%,6%,9%), Copper & Brass Electrodes.

S.NO	T_{ON} (ms)	I_p (A)	V (V)	T_{OFF} (ms)	SR (μm)				
					Al6061+3%SiC	Al6061+6%SiC	Al6061+9%SiC	COPPER	BRASS
1	200	6	30	100	6.947	2.859	5.24	6.05	3.809
2	200	8	40	200	7.805	3.203	6.038	7.705	3.326
3	200	10	45	500	6.411	4.025	6.039	7.723	3.954
4	500	6	30	500	8.69	3.675	7.303	8.426	5.766
5	500	8	40	100	8.512	3.234	7.874	6.854	4.633
6	500	10	45	200	8.425	4.4	8.742	10.754	4.561
7	900	6	30	200	8.354	5.551	7.55	6.119	6.289
8	900	8	40	500	10.95	5.597	7.458	7.33	3.700
9	900	10	45	100	11.602	6.621	8.904	9.793	8.137

Table 3

Calculation of Regression coefficients for SR.

Regression Coefficients	Al6061+3% SiC	Al6061+6% SiC	Al6061+9% SiC	Copper	Brass
Constant	3.21	1.97	-1.13	-2.19	6.05
T_{ON}	0.00259	0.003751	-0.00063	-0.00009	0.00332
I	2.26	1.013	5.648	2.94	-1.55
V	-0.365	-0.204	-0.945	-0.339	0.172
T_{OFF}	0.0005	0.00041	0.02584	0.0293	0.01077
$I * T_{OFF}$	-0.01158		-0.003826	-0.00365	
$V * T_{OFF}$	0.0024				
$T_{ON} * I$			-0.00763	-0.000102	0.00364
$T_{ON} * V$			0.001643		-0.00062
$T_{ON} * T_{OFF}$					-0.00002

The value of the surface roughness of the machined surface is found using a Surf Test.

The following images shows the roughness values in microns for the trials conducted. (Ref. Fig.3)

The adequacy of the model was then tested by Fisher test. As per this technique, F-ratio of the model developed does not exceed the standard tabulated value of f-ratio for a 95% confidence level. Hence the model was adequate. The significance of the coefficients was checked by using student's t-test and only the significant coefficients were used to develop final mathematical model. The final models in coded form for the SR for Al6061 + SiC(3%, 6%, 9%), Copper and Brass tool are given below.

Regression Equation For Surface Roughness

$$SR \text{ (Al6061+ 3\% SiC)} = 3.21 + 0.00259 T_{ON} + 2.26 I - 0.365 V + 0.0005 T_{OFF} - 0.01158 I * T_{OFF} + 0.00240 V * T_{OFF}$$

$$SR \text{ (Al6061+6\% SiC)} = 1.97 + 0.003751 T_{ON} + 1.013 I - 0.204 V + 0.00041 T_{OFF}$$

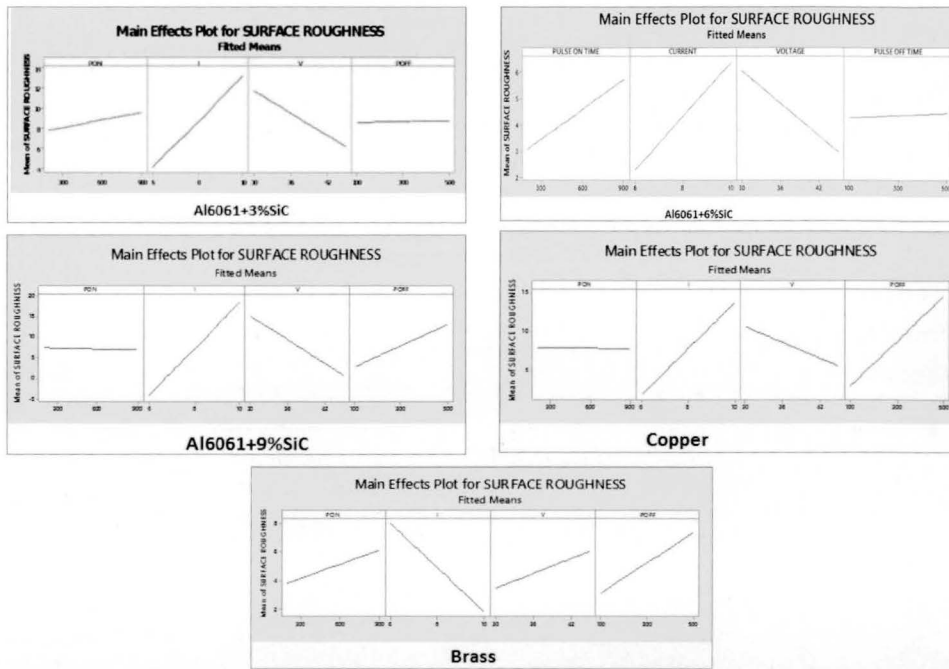


Fig. 4. Main effects of surface roughness

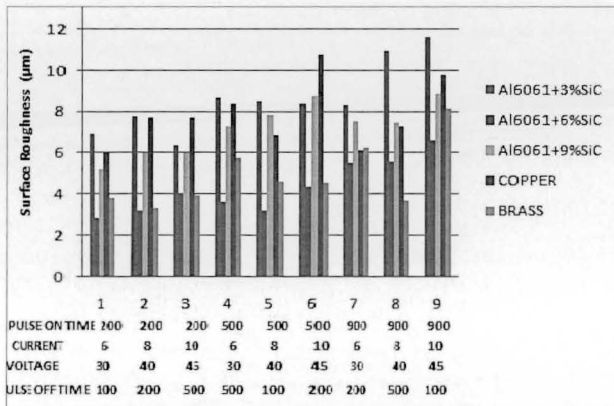


Fig. 5. SR Vs input parameters

$$SR (Al6061+9\% SiC) = -1.13 - 0.00063 T_{ON} + 5.648 I - 0.945 V + 0.02584 T_{OFF} - 0.00763 T_{ON} * I + 0.001643 T_{ON} * V - 0.003826 I * T_{OFF}$$

$$SR (Copper) = -2.19 - 0.00009 T_{ON} + 2.94 I - 0.339 V + 0.02930 T_{OFF} - 0.00365 I * T_{OFF} - 0.000102 T_{ON} * I$$

$$SR (Brass) = 6.05 + 0.00332 T_{ON} - 1.55 I + 0.172 V + 0.01077 T_{OFF} + 0.00364 T_{ON} * I - 0.000620 T_{ON} * V - 0.000020 T_{ON} * T_{OFF}$$

4. Results & Conclusions

The experiments were conducted as per design matrix by Taguchi methodology. The following conclusions are made from the work carried out.

- Al6061 + SiC (with SiC of 3%) tool had a minimum metal Surface Roughness of 6.411µm for a combination of input variables Pulse on time: 200µs, Current: 10A, Voltage: 45V, Pulse off time: 500µs.
- Al6061 + SiC (with SiC of 6%) tool had a minimum metal Surface Roughness of 2.859µm for a combination of input variables Pulse on time: 200µs, Current: 6A, Voltage: 30V, Pulse off time: 100µs
- Al6061 + SiC (with SiC of 9%) tool had a minimum metal Surface Roughness of 5.24µm for a combination of input variables Pulse on time: 200µs, Current: 6A, Voltage: 30V, Pulse off time: 100µs
- Copper tool had a minimum metal Surface Roughness of 6.05µm for a combination of input variables Pulse on time: 200µs, Current: 6A, Voltage: 30V, Pulse off time: 100µs
- Brass tool had a minimum metal Surface Roughness of 3.326µm for a combination of input variables Pulse on time: 200µs, Current: 8A, Voltage: 40V, Pulse off time: 200µs
- From the above Observation (Table 2) the minimum surface roughness is 2.859µm for the tool Al6061+ SiC (with SiC of 6%)

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