EVALUATION OF SURFACE ROUGHNESS AND MRR OF EN18 STEEL TOOL IN EDM PROCESS

BURRA PRASAD
M.Tech, Production Engineering,
Ellenki Engineering College Of Siddipet
Email: prasadburra691@gmail.com

G.VINOD REDDY
Dept., Mechanical Engineering
Designation: Assitant Professor
E-Mail: vinod.reddy315@gmail.com

ABSTRACT

Electrical discharge machining is one of the earliest nontraditional machining, extensively used in industry for processing of parts having unusual profiles with reasonable precision. In the present work, an attempt has been made to model material removal rate, electrode wear rate, and surface roughness through response surface methodology in a die sinking EDM process. The optimization was performed in two steps using one factor at a time for preliminary evaluation and a Box-Behnken design involving three variables with three levels for determination of the critical experimental conditions. Pulse on time, pulse off time, and peak current were changed during the tests, while a copper electrode having tubular cross section was employed to machine through holes on EN 353 steel alloy work piece. The results of analysis of variance indicated that the proposed mathematical models obtained can adequately describe the performances within the limits of factors being studied. The experimental and predicted values were in a good agreement. Surface topography is revealed with the help of scanning electron microscope micrographs.

After the results have studied it is found out that current is most significant value followed by pulse time and duty cycle is least significant for both MRR and SR. both MRR and SR increased nonlinearly with the increases in current. As pulse time increases MRR decreases slightly and with increase in duty cycle it increases insignificantly. But SR first increases with increases in pulse time but after 500µs it decreases. For duty cycle also SR increases up to 65% then started decreasing.

INTRODUCTION

Electrical discharge machining also known as EDM has been proven as an alternative process for machining complex and intricate shapes from the conductive ceramic composition. It is a non-conventional machining method. In electrical discharge machining process electrical energy is used to cut the material to final shape and size. Efforts are made to utilize the whole energy by applying it at the exact spot where the operation needs to be carried out. There is no mechanical pressure existing between work piece and electrode as there is no direct contact. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material.

It is generally used for machining of very tough and brittle electrically conducting material. In this experiment EN18 steel is used as work piece and copper is used as tool. EN series is a popular steel tool. There are three input variable parameters used which are current, pulse time and duty cycle. Taguchi method is used to create L9 orthogonal array of input variables. MRR and Surface Roughness is found out and the effects of the input variables on this characteristics are studies in this experiment. The EDM machine used in this experiment is ELECTRONICA - ELECTRAPLUS PS 50ZNC (die sinking type) EDM.

LITERATURE REVIEW

In this section I have discussed some of the research paper based on Electrical Discharge Machining. The experiment or studies carried out in these papers are concerned with different parameter in EDM such as voltage, current, duty cycle, Ton , Toff etc and its effects on machining characteristics like material removal rate (MRR), and surface roughness.

- Boujelbene et al. [1] carried out experiment on two electrical discharge machines to obtain high surface finish and other machining aspects. By doing experiment they found out increasing discharge energy, impulse the MRR increases and surface becomes rougher and white layer thickness increases. This happens because of more melting and recasting of material. They also found that if the degree of induce stream exceeds the maximum tensile stress of material cracking will occur.
- Hwa-Teng Lee et al. [2] have done experiments and found out that the value of MRR and surface roughness increases with increasing the values of pulse current but after certain value the MRR and SR reduces due to expansion of electric plasma. The pulse current affects the surface crack density while the pulse on duration influences the degree of crack opening. The residual stress induced by hole drilling increases with increasing values of pulse current and pulse on time.
- K.M. Patel et al. [3] investigated the machining characteristics, Surface integrity and material removal mechanism of Al_2O_3-SiCw-Tic with EDM. They concluded that the surface roughness and recast layer increases with current and pulse on time. The material removes because of dissociation melting and evaporation and to some extent oxidization and decomposition at lower current and thermal spelling at higher current.
- J.C. Rebelo et al. [4] have performed experiment on ROBOFORM 200-"Charmilles Technology" taking martensitic steel as workpiece. They vary time and pulse current. Many experimental techniques used for assessing surface integrity. They found the penetration and depth of cracks in the recast layer increases with current, cementite white layer formed at the white layer and different heat affected zone were observed which depends on machining energy. Residual stress of tensile nature determined.
- A. hascalik and U. Caydas [5] conducted the EDM experiments on model M25A with specimen as Ti-6Al-4V and then the same specimen machined by AECG process on model ECG-SGI12X36. They found that surface is rough because of debris and recast layer formed on surface. In AECG with increasing flow rate cleaner surface were observed. It is possible to get EDM damages free surface by AECG
- Y.S. Liao et al. [6] have designed pulse-generating circuit by removing the high voltage discharging circuit from original circuit. They found that a dc pulse generating circuit of positive polarity can achieve a better surface roughness. They did experiment by varying different parameter like voltage, current, capacitance and appropriate values are chosen and a surface roughness of 0.22µm is achieved.
- M. Kiyak and O. Cakir [7] had

performed the experiment on AJAN-EDM982 machine. They found out that with low current and pulse on time and high pulse off time high surface finish can be produced but MRR will be low. This combination used in finishing operation. With high pulse on time, pulse current and low pulse off time I get high MRR but low surface finish, this is used for rough machining step of EDM process.

- A. Hascalik and U. Caydas [8] had performed the experiment on sodick A32OD/EX28 wire EDM. After experiment they found four layer such as recast layer, white layer, annealed area and parental material. By increasing voltage and pulse duration the density in white layer increases. The cutting surfaces are harder than bulk material because of white layer and heat affected zone is softer in quenched and tempered specimen. Surface roughness increases with increasing in pulse duration and voltage.

EXPERIMENTAL SETUP

The whole experiment was conducted on Electrical Discharge Machine which is a die sinking type EDM machine of model ELECTRONICA - ELECTRAPLUS PS 50ZNC. The voltage set as 40V. The polarity of work piece set as positive (anode) and electrode as negative (cathode). EDM oil is taken as dielectric fluid.

The EDM consist of following parts

- Power generator and control unit
- XY working table
- Dielectric reservoir, pump, and circulation table
- The tool holder
- Working tank with work holding device
- The servo system for feeding the tool

Fig. 3.1 Dielectric reservoir

Fig. 3.2 Control unit

DESIGN OF EXPERIMENTS ANALYSIS

Taguchi design

Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two-, three-, four-, five-, and mixed-level fractional factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes

I have used Taguchi Method. Dr. Genichi Taguchi of Nippon Telephones and Telegraph Company, Japan developed this method which is based on Orthogonal Array experiment to improve the quality of manufactured products and nowadays used in engineering. Taguchi Method can be defined as the quality control methodology that combine control charts and process control with product and process design to achieve a good design. It aims to reduce product variability with a system for developing specifications and designing them into product or process. The design of experiment is used to find the best combination of parameters used as input values in an orthogonal array.

In this experiment I have used three input parameters:

1. Ip
2. T_{on}
3. T_{au}

There are 3 variables so the design becomes a 3 level 3 factorial Taguchi design. L9 orthogonal array was chosen for the experiment to be conducted

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Table no. 3.1 Variable Machining Parameters and their Level

Machining Parameter	Unit	Levels		
		1	2	3
Discharge Current	A	1	5	9
Pulse on time	µs	100	500	1000
Duty Cycle (Tau)	%	50	65	85

I have fixed some of the machining parameters which are as follows:
Voltage = 40V
ASEN = 3
SEN = 6 T_w = 0.8
T = 0.6
Polarity = +ve
Once the experimentation was completed, the workpieces were cleaned thoroughly using acetone and the final individual weight of electrode was measured. Material removal rate was calculated by using the following formula:

$$\text{MRR} = \frac{V\,(\text{mm}^3)}{t\,(\text{min})}\,(\text{mm}^3/\text{min}),$$

Where V is volume of material removed and $t$is the machining time. Electrode wear rate was calculated by using the following formula:

$$\text{EWR} = \frac{E_b - E_a\,(\text{g})}{t\,(\text{min}) * \text{density}\,(\text{g/mm}^3)}\,(\text{mm}^3/\text{min}), \quad (2)$$

where Eb and Ea are the weights of electrode material before and after machining, respectively, and t is the machining time. The weights of the electrodes were measured using a balance. Surface roughness measurements were carried out at the sidewall of the holes using a Brand-Mitutoyo Surftest.

RESULT AND DISCUSSION

In this section I have discussed the result obtained from the experiment and analyze the effect of different parameters on MRR and Surface Roughness.

Table no. 4.1 Observation Table

Expt. no.	Pulse time I (A)	Pulse time T_{on} (µs)	Duty Cycle T_{au} (%)	MRR (mm^3/min)	Surface Roughness (µm)
1	1	100	50	0.24221	3.8
2	1	500	65	0.21685	7.13
3	1	1000	85	0.10205	6.13
4	5	100	65	2.03954	7.4
5	5	500	85	2.00242	8.26
6	5	1000	50	0.89272	7.13
7	9	100	85	5.76275	7.8
8	9	500	50	5.58673	12.67
9	9	1000	65	5.38266	12.33

ANALYSIS AND DISCUSSION OF MRR

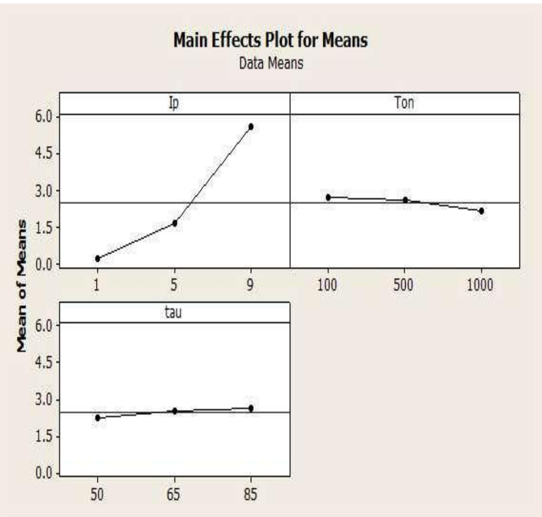

Fig 4.1 Main Effects Plot for MRR

The MRR increases as the value of Ip increases. The rate of increase in value of MRR is more for the range of Ip (5A to 9A) than the range of Ip (1A to 5A).
The MRR decreases very slightly as I increases the values of Ton from 100µs to 500µs. As I increase the value further from 500µs to 1000µs the MRR value decreases more rapidly.
MRR increases as the value of duty cycle increases from 50% to 65%. But after 65% MRR increment is very slight.

Linear Model Analysis: Means versus Ip, Ton, tau:

Table No.4.2 Estimated Model Coefficients for MRR

Term	Coef.	SR Coef.	T	P
Constant	2.46944	0.08983	27.490	0.001
Ip 1	-2.28240	0.12704	-17.966	0.003
Ip 5	-0.82455	0.12704	-6.490	0.023
T_{on} 100	0.21206	0.12704	1.699	0.237
T_{on} 500	o.13157	0.12704	1.063	0.409
T_{au} 50	-0.22298	0.12704	-1.809	0.212
T_{au} 65	0.07691	0.12704	0.605	0.606

S = 0.2695 R-Sq = 99.7% R-Sq(adj) = 98.8%

Table No.4.3 Analysis of Variance for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ip	2	46.6271	46.6271	23.3136	321.01	0.003
T_{on}	2	0.5411	0.5411	0.2705	3.73	0.212
T_{au}	2	0.2465	0.2465	0.1232	1.70	0.371
Residual Error	2	0.1453	0.1453	0.0726		
Total	8	47.5599				

Table No.4.4 Response Table for MRR

Level	Ip	T_{on}	T_{au}
1	0.1870	2.6815	2.2396
2	1.6449	2.6010	2.5463
3	5.5764	2.1258	2.6224
Delta	5.3894	0.5557	0.3828
Rank	1	2	3

From the ANOVA table it is found that only Ip has significant value as its P value is less than 0.05. The P value of T_{on} and T_{au} are greater than 0.05. The most significant value is Ip followed by T_{on} and T_{au} is least significant.

The standard deviation of error, S = 0.2695 And R^2 = 99.7%

ANALYSIS AND DISCUSSION OF SURFACE ROUGHNESS

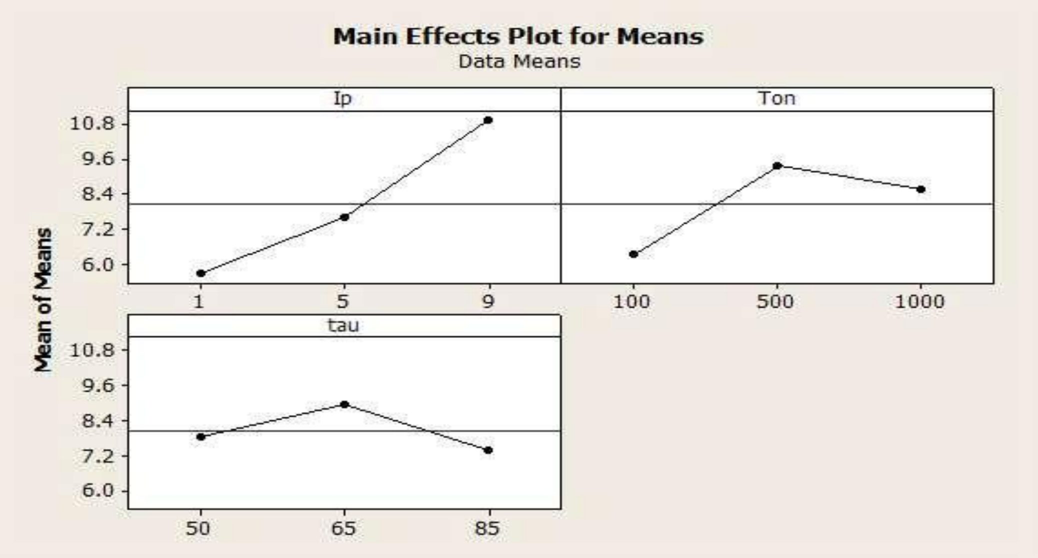

Fig 4.3 Main Effects Plot for SR

Surface Roughness increases with the increase in the value of Ip. From 1A to 5A, SR increases with a good rate but from 5A to 9A it increases rapidly.
Surface Roughness Increases with increasing in values of T_{on} from 100µs to 500µs after that SR decreases as T_{on} increases from 500µs to 1000µs.
Surface Roughness increases as the T_{au} increases from 50% to 65%, but after 65% as I increase T_{au} up to 85% the value of SR decreases.

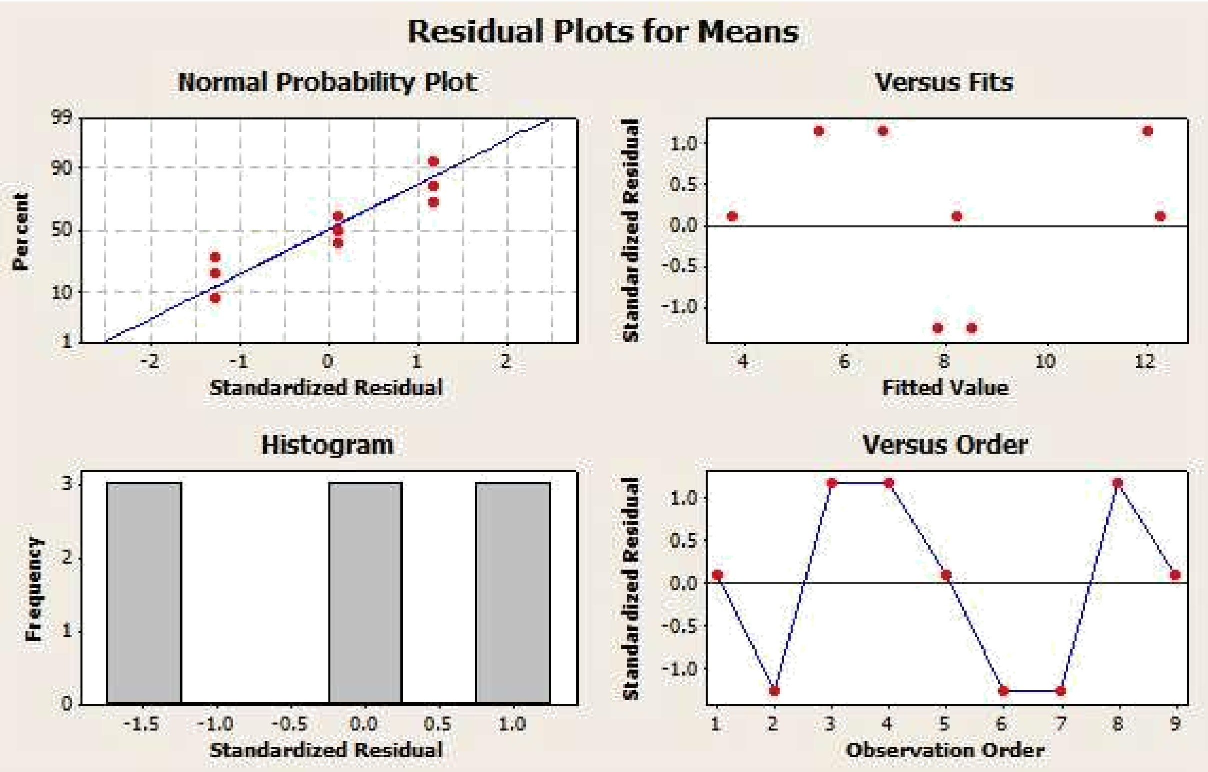

Fig 4.4 Residual Plots for SR

Table No.4.5 Estimated Model Coefficients for SR

Term	Coef.	SR Coef.	T	P
Constant	8.0722	0.3994	20.210	0.002
Ip 1	-2.3856	0.5649	-4.223	0.052
Ip 5	-0.4765	0.5649	-0.842	0.488
T_{on} 100	-1.7389	0.5649	-3.078	0.091
T_{on} 500	1.2811	0.5649	2.268	0.151
T_{au} 50	-0.2056	0.5649	-0.364	0.751
T_{au} 65	0.8811	0.5649	1.560	0.259

S = 1.198 R-Sq = 95.5% R-Sq(adj) = 81.9%

Table No.4.6 Analysis of Variance for SR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ip	2	42.309	42.309	21.154	14.73	0.064
T_{on}	2	14.624	14.625	7.312	5.09	0.164
T_{au}	2	3.825	3.825	1.912	1.33	0.429
Residual Error	2	2.872	2.872	1.436		
Total	8	63.629				

Table No.4.7 Response Table for SR

Level	Ip	T_{on}	T_{au}
1	5.687	6.333	7.867
2	7.597	9.353	8.953
3	10.933	8.530	7.397
Delta	5.247	3.020	1.557
Rank	1	2	3

From above ANOVA table it is found that neither of three are significant values as P of every parameter is greater than 0.05. But for Ip P is slightly more than 0.05, therefore Ip is slightly significant whereas T_{on} less significant and T_{au} is least significant as P of T_{au} is more.

The standard deviation of error, S = 1.198
And R^2 = 95.5%

CONCLUSION

The experiments are done in Electric Discharge Machine, model ELECTRONICA -ELECTRAPLUS PS 50ZNC (die sinking type) using three variable parameters Ip, T_{on} and T_{au}. The aim of this experiment is to find out Material Removal Rate and Surface Roughness and the effects of the variables used on these characteristics. The electrode used in this experiment is copper and En18 steel tool is used as work piece. In this experiment Taguchi method is used to create an L9 orthogonal array and experiments are done accordingly. By doing experiments following conclusion can be drawn:

- Ip is more significant value for MRR while significance of T_{on} is less and that of T_{au} least. As I increase Ip, MRR increases nonlinearly. As T_{on} increases MRR decreases slightly and with increase in T_{au} it increases insignificantly.
- For Surface Roughness Ip is most significant then T_{on} and T_{au} is least significant. As Ip increases SR increases and it increases rapidly as Ip values is more. As I increases T_{on} SR increases but after 500µs it started decreasing. Similarly for T_{au} it increases up to 65% and then decreases.

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