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

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By

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CERTIFICATE

This is to certify that the thesis entitled, "**EVALUATION OF SURFACE ROUGHNESS AND MRR OF EN18 STEEL TOOL IN EDM PROCESS**" submitted by Mr. PARBESH AGRAWAL in partial fulfillment of the requirements for the award of *Bachelor of Technology* Degree in Mechanical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma.

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ABSTRACT

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 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.

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.

ABBREVIATIONS AND SYMBOLS

µm	Micrometer
µs	Microsecond
EDM	Electrical Discharge Machining
V	Voltage
A	Ampere
Ip	Discharge Current
MRR	Material Discharge Material
SR	Surface Roughness
T_{on}	Pulse on Time
T_{off}	Pulse off time
T_{au}	Duty Cycle
T_w	Tool Work Time
$T_{\uparrow}$	Tool life time
SEN	Sensitivity
ASEN	Anti-arc Sensitivity
DF	Degree of freedom
S	Standard error of Deviation
R^2	Amount of variation

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CHAPTER 1 INTRODUCTION

1.1 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.

1.2 HISTORY

EDM was first discovered by English scientist joseph priestly in 1770. But at that time it was imprecise and riddle with failure. Electrical discharge machining takes full advantage when two Russian scientists Mr. & Mrs. Lazarenko learned how the erosive effect can be controlled and utilize for machining in 1943. From mid 1970s wire EDM began to be a viable technique that helped shape the metalworking industry I see today. From mid 1980s EDM techniques transferred to a machine tool. Nowadays wire EDM is used for machining harder material with precision cutting.

1.3 PRINCIPLES OF EDM

When a different potential is applied between two conductors emerge in a dielectric medium the fluid will ionized. If the potential difference reaches a high value a spark will occur. The control erosion of material is achieved by rapidly recurring spark. Discharge occurs in both the electrode, the tool and work piece. The tool is made as cathode and work piece as anode. The

MRR and surface integrity varies as I vary the pulse energy, pulse time, pulse current and many other factors.

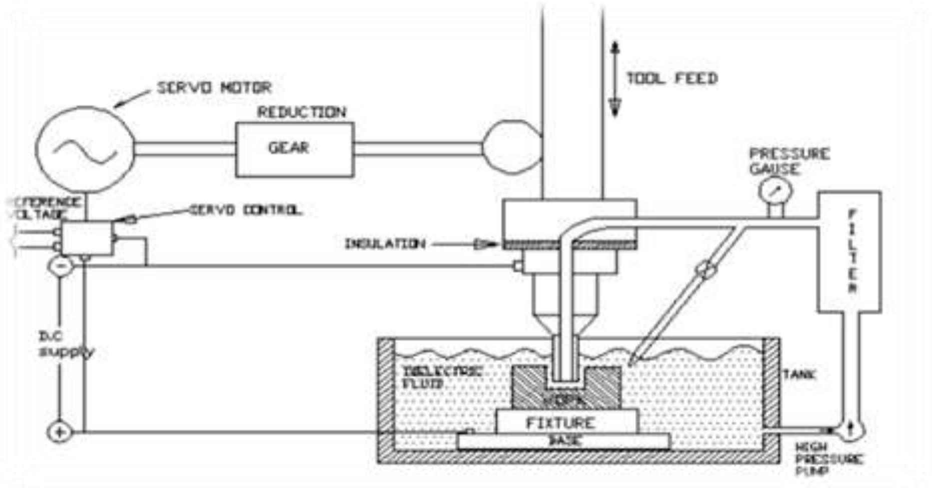

Fig1.1 Experimental setup

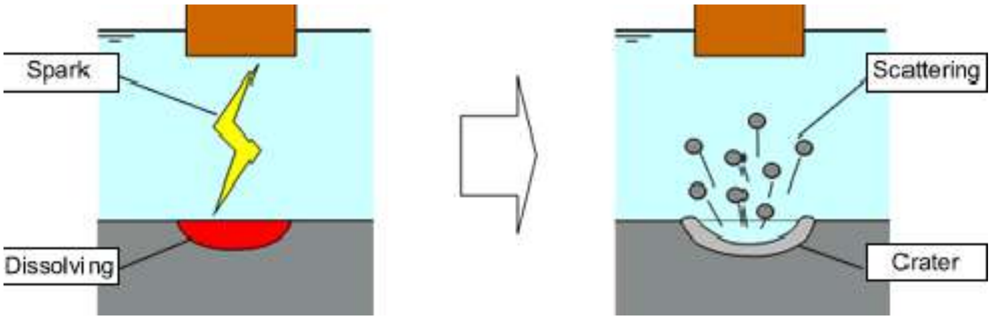

Fig 1.2 Effects of spark

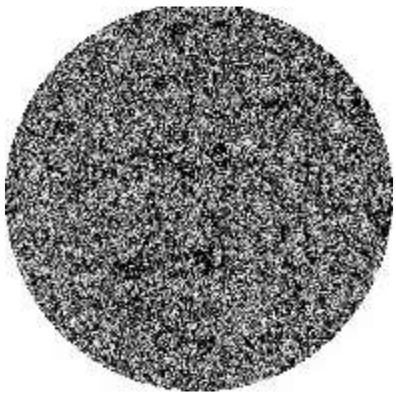

Fig 1.3 the surface by discharge machining

If both the electrodes are made of same material then it has been found that the greater erosion takes place on the positive electrode. Therefore in order to remove maximum metal and minimum tool wear the tool is made as cathode and w/p as anode. The two electrodes are separated by dielectric medium such as paraffin oil, white spirit, kerosene, deionized water.

The EDM is also called as a machining method by copying as the work piece takes the shape and size of electrode which is generally made of material like copper.

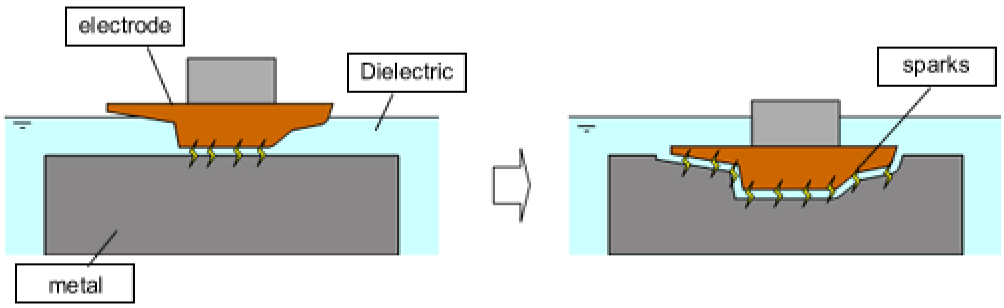

Fig 1.4 Copying of shape and size by work piece

1.4 TYPES OF EDM

EDM enables different types of machining some of which are conventional as milling and die sinking others have its own characteristics. But simple and general classification can be done based on application:

1. Die sinking EDM
2. Wire EDM
3. EDM milling
4. Wire Electrical discharge grinding

1.4.1 Die sinking EDM

In this type of EDM the tool electrode has the complementary form of finished work piece and literally sinks into the rough material. In this I get more accuracy but the machining time is more. It is also known as volume EDM or cavity type EDM.

1.4.2 Wire EDM

In this type of EDM the electrode is a wire that cuts through the work piece and renewed constantly to avoid rapture. This wire is cheaper than the electrode. In this method the machining time is short but the operation should be done on ruled surfaces and wire may bend which cause substantial shape error. It is mostly used when lower residual stress is required.

1.4.3 EDM milling

It is used when a large holes or complex geometry is required. Usually in this method a rotating cylindrical electrode follows a path through the work piece, yielding the desired final geometry.

1.4.4 Wire Electrical Discharge Grinding

It is used when small holes are used. In this the polarity of the electrode and workpiece is reversed so that les material removal takes place from the workpiece.

1.5 IMPORTANT PARAMATERS

1.5.1 T_{on} :

It is also known as spark on time or pulse width. It means duration of spark. Its unit is µs (microsecond). Range is 0-1000µs.

1.5.2 T_{off}:

It is also known as spark off time or downtime. It means the time in between the sparks generated. In this time the molten metal is removed. It is set in the range between 0-1000µS.

1.5.3 Voltage (V):

The potential difference applied between the electrode and the workpiece. It is set in the range of 40-200V.

1.5.4 Discharge current (Ip):

It means the electric current value of the spark. It is shown in the unit of amp(A).it is set in the range of 0.5-400amp.

1.5.5 Duty cycle (T_{au}):

It is the ratio of Ton and total cycle time.

$T_{au} = T_{on} /(T_{on}+T_{off})$

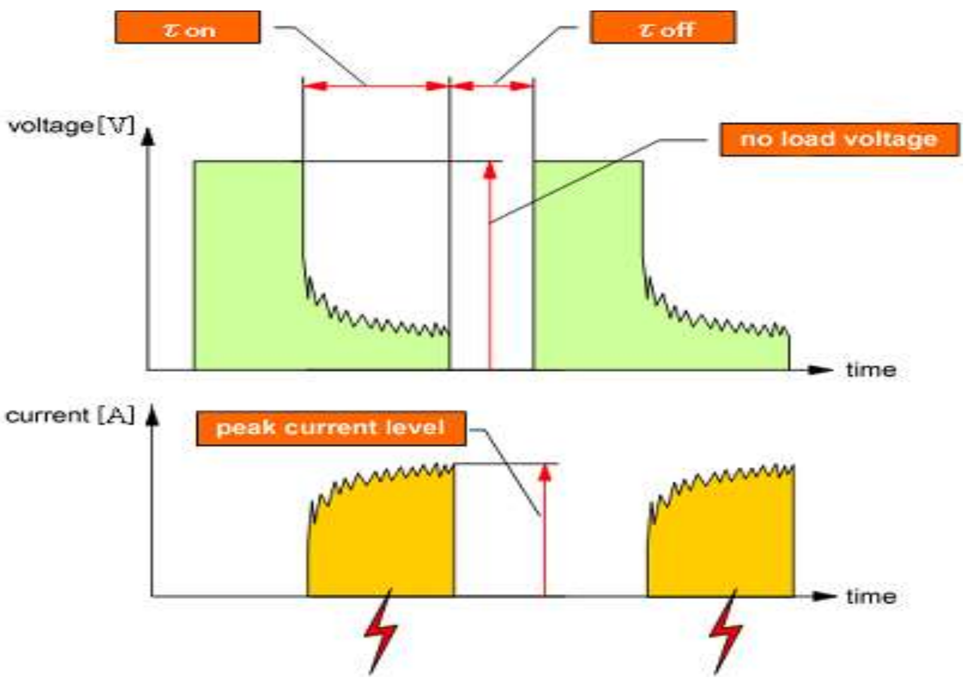

Fig 1.5 Voltage v/s time and Ip v/s time

1.6 ADVANTAGES OF EDM

- Complex shapes can be machined which is difficult in conventional cutting tools.
- In EDM process no cutting force generated as there is no contact between workpiece and electrode so it permit the production of small and fragile surfaces.
- Extremely hard material can be machined without deformation
- Any types of conductive material can be machined
- Burr free edges can be produced
- Intricate details and very high surface finish can be obtained
- Fine holes can be drilled easily

1.7 DISADVANTAGES OF EDM

- MRR is very less compare to other machining operation like chip machining
- The work piece must be a electrically conducting material
- The tool wear is excessive during machining
- Power consumption is more
- Different parameter have to be optimized to get a good result
- Lead time is needed to produce specific and consumable shapes
- It is difficult to reproduce sharp corners because of tool wear

CHAPTER 2 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, T_{on} , T_{off} 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.

CHAPTER 3 EXPERIMENTATION

In this section, I have discussed about the experimental work done prior to the execution of the work which includes L9 orthogonal array using Taguchi design, selection of material, experimental setup, tool design, and how to calculate MRR and surface roughness.

3.1 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 workpiece 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

3.2 **SELECTION OF MATERIAL**

EN-18 steel tool is a part of popular EN series steels. EN steels are mixture of carbon and alloys. EN series came during the world war time and it is the outcome of British standard (BS970) steels. This steel generally contains carbon, Magnesium, Silicon, Sulphur, Phosphorous, Chromium, Nickel and Molybdenum.

The chemical composition of EN18 steel (by weight):

Carbon – 0.4 %

Silicon – 0.2 %

Magnesium – 0.75 %

Sulphur – 0.04 %

Phosphorous – 0.04 %

Chromium – 1.01 %

3.3 SELECTION OF TOOL

There are variety of material can be used as tool for EDM process like copper, brass aluminium alloys, silver alloys etc. the electrode used in this experiment is copper. The shape of copper is cylindrical with diameter 21 mm.

Fig.3.3 Copper tool

3.4 EVALUATION OF MRR

MRR is the rate at which the material is removed from the work piece. Its unit is mm^3/s. the material is removed from the work piece because of series of recurring spark between the two electrodes. The MRR can be defined as the rate of material removed per second or the ratio of change in volume of workpiece during machining divided by duration of machining.

$$MRR = (W_i - W_f) / t \times \rho$$

Where, W_i = initial weight of material

W_f = final weight of material after experiment

t = machining time = 5 min

ρ = density of material = 7.84 gm/cc^3

3.5 EVALUATION OF SURFACE ROUGHNESS

Surface roughness or simply called as roughness is the measure of surface texture. Its unit is μm. it can be defined as the vertical deviation of real surface from ideal surface. If the deviation is more, it is said as rough surface and if the deviation is less, it is said as smooth surface. Surface roughness generally measured using portable type profilometer, talysurf.

3.6 DESIGN OF EXPERIMENTS ANALYSIS

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.

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

$T_{\uparrow}$ = 0.6

Polarity = +ve

CHAPTER 4 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

4.1 ANALYSIS AND DISCUSSION OF MRR

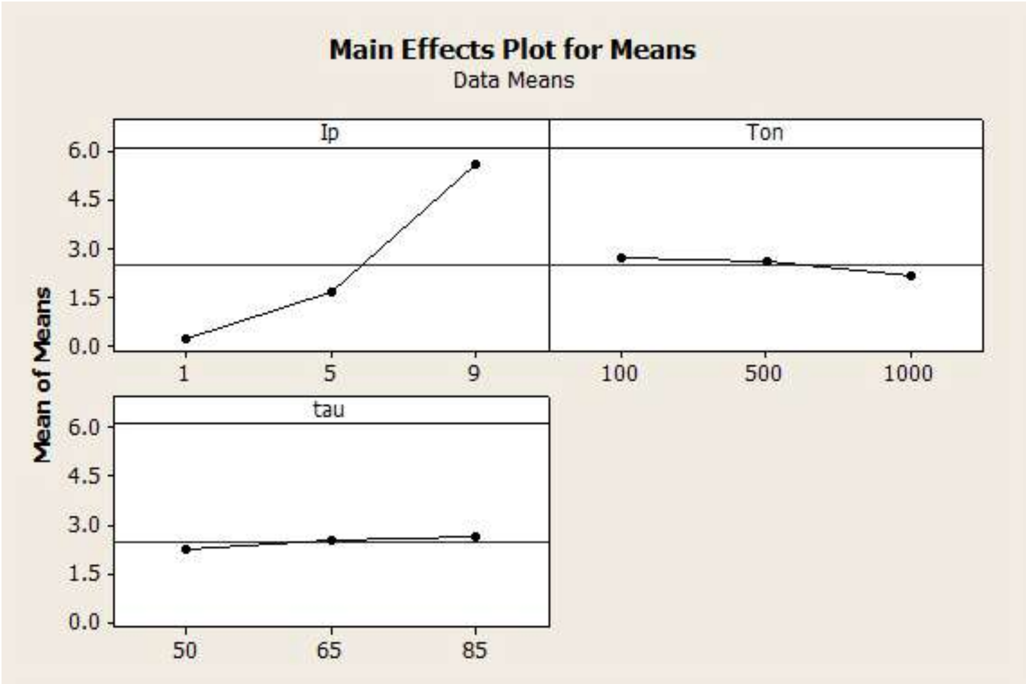

Fig 4.1 Main Effects Plot for MRR

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.

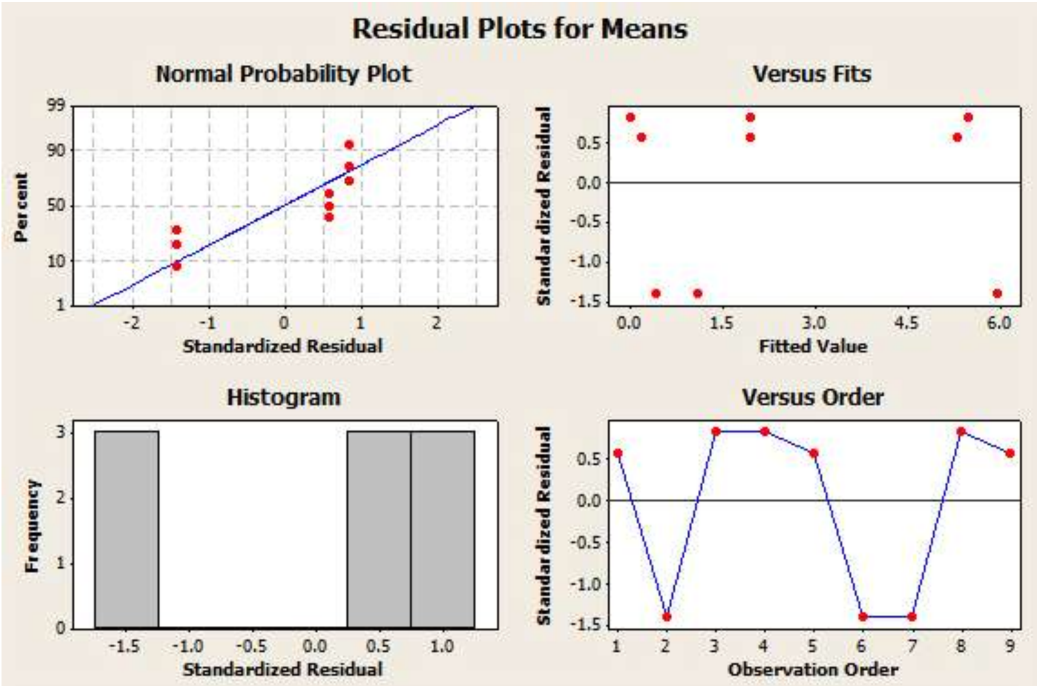

Fig 4.2 Residual Plots for MRR

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%

4.2 ANALYSIS AND DISCUSSION OF SURFACE ROUGHNESS

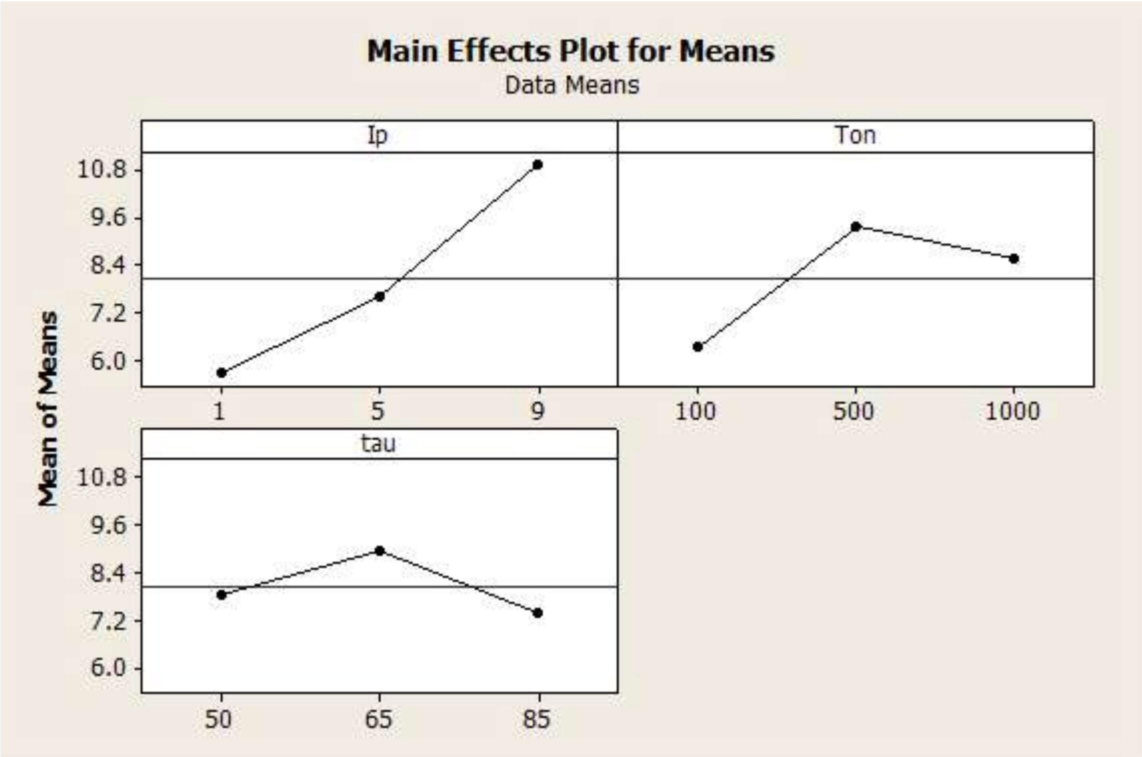

Fig 4.3 Main Effects Plot for SR

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.

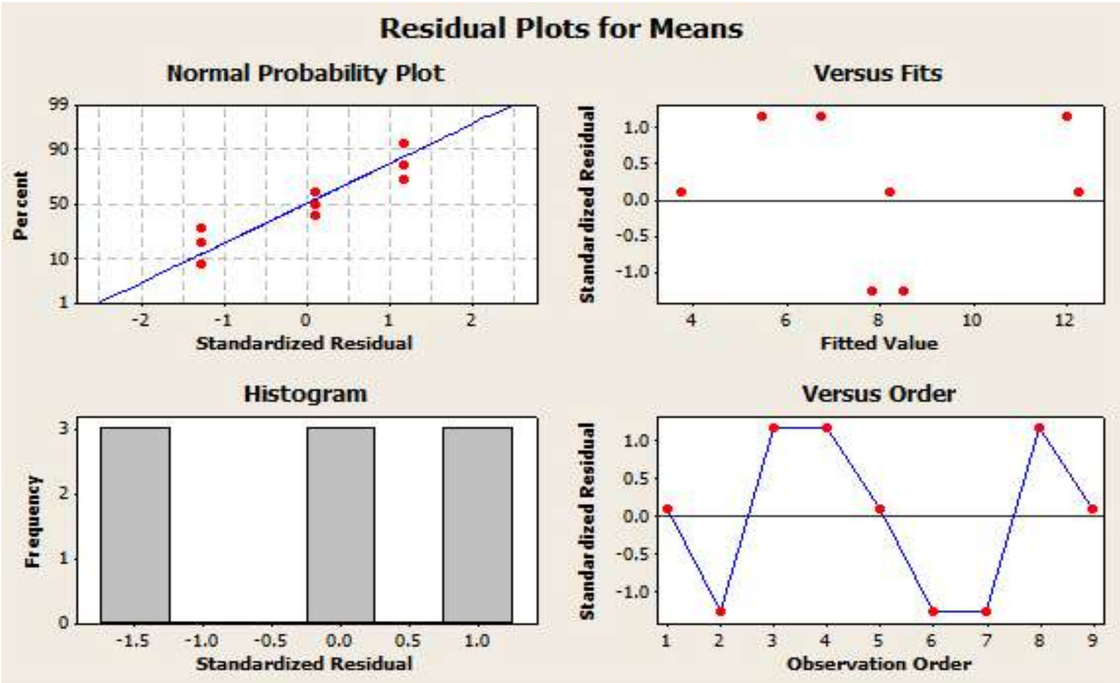

Fig 4.4 Residual Plots for SR

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%

CHAPTER 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.

CHAPTER 6 APPENDIX

In this section, I have discussed about the machines and equipment used for conducting the experiments.

- EDM Machine

  All the experiment is conducted on EDM machine of model ELECTRONICA- ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap).

Fig 6.1 EDM machine

- Weight Balance

  To measure the weight of workpiece before and after each experiment I used precision balance of brand SHINKO DENSHI Co. LTD, JAPAN, and Model DJ 300S. The capacity of this machine is 300gm and accuracy is 0.001gm.

Fig 6.2 Weight Balance

- Talysurf:

  To measure the values of Surface Roughness of specimen I used portable type profilometer talysurf (Model: Taylor Hobson, Surtronic 3^+)

Fig 6.3 Talysurf

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