ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

EXPERIMENTAL STUDY OF EFFECT OF MACHINING PARAMETERS ON MACHINING OF STEEL EN-24 ON EDM

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ABSTRACT

The present experimental research for parametric optimization of EDM studies the process parameters that are affecting the machining performance and productivity of EDM. A combined approach is used for the optimization of parameters and performance characteristics based on Taguchi method. The design of experiments is based on Taguchi's L9 orthogonal array. The response table and response graph for each level of machining parameters are obtained from Taguchi method to select the optimum levels of machining parameters. In the present work, the machining parameters are current(I_p), pulse on time(T_{on}) and pulse off time(T_{off}) which are optimized for maximum material removal rate (MRR), minimum tool wear rate (TWR), minimum surface roughness (SR) electro discharge machining of Steel EN-24. Analysis of Variance is also used to find out variable affecting the various responses mentioned above.

I. INTRODUCTION

Electrical discharge machining is basically a non-traditional non-conventional non-contact material removal process which is widely use to produce dies, punches, moulds, finishing parts for aerospace and automotive industry, machining of ceramics and composites and surgical components and nozzle. The working process of EDM process is based on the thermoelectric energy. This energy is created between a work piece and an electrode submerged in a dielectric fluid with the passage of electric current. A necessary condition for producing a discharge is ionization of dielectric[1]. A suitable voltage is applied and intensity of dielectric field between them builds up. The electrons move from the surface of cathode and are impelled towards the anode under field forces. While moving, the electrons strike the neutral molecules of dielectric and causes ionization. When this happens, there is an avalanche of electrons flowing towards anode, resulting in a discharge of energy which is seen in form of spark. The discharge leads to the generation of extremely high temperature causing melting of metal in the form of liquid drops dispersed into space surrounding the electrodes by the explosive pressure of gaseous product in the discharge. The continuous flushing of the dielectric is necessary for efficient removal of debris.There are important parameters of EDM as:

- **Spark on-time (T_{on}):** The duration of time (µs) the current is allowed to flow per cycle.
- **Spark off-time (T_{off}):** the duration of time(µs) in between the sparks generated. During this time the molten material gets removed from the gap between the electrode and the workpiece.
- **Peak current(Discharge Current)(Ip):** It is the current flowing through the electrode and is measured in ampere

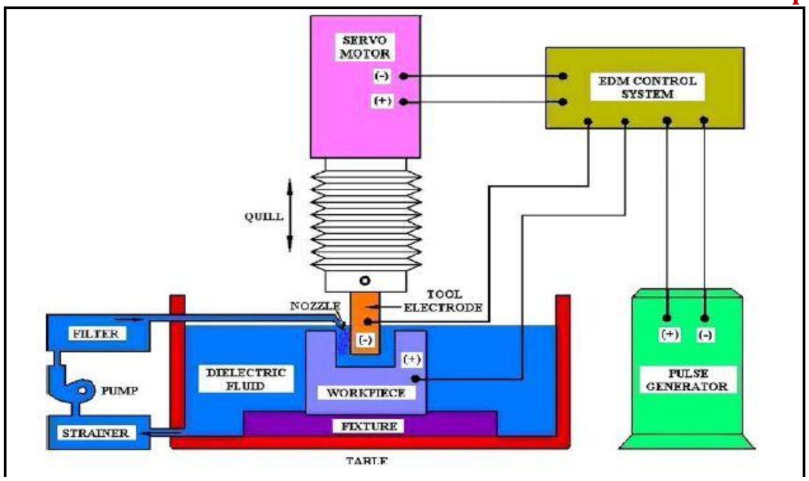

Figure 1: Setup of EDM Machine [2]

II. EXPERIMENTATION

A. MATERIAS:

The material used for this work is steel EN-24 (AISI 4340) of 5 mm thickness and 10 mm diameter (density 7.85 gm/cm^3) . The material is hardened to a hardness of 217BHN. The electrode used is electrolytic copper (99.9% pure) of 8.96 gm/cm^3 density with a melting point of 1083^{0}C. These electrodes are cylindrical in shape with a 25mm length and 3 mm diameter.

B. EDM MACHINE:

The machine used is Electronica- ZNC-25 machine with NC control in Z-direction. The dielectric fluid used for the EDM was a mineral oil EDM-30. Polarity of the electrode is negative and that of the work piece is positive.

C. DESIGN OF EXPERIMENT:

Design of experiments (DOE) is a statistical technique introduced by Sir R.A. Fisher in England in the early 1920's.Design of experiments helps us to study the effect of several variables simultaneously and also to study the interrelationships and interactions between them. Taguchi approach of design of experiments is a tool used for reducing the inherent variability in a product or a process. It reduces the number of experiments and cost of the product or the process. It improves the quality of the product and the process. The breif proceedure of taguchi method is as under

- Identify the objective function
- Select the factors to be evaluated
- Identification of uncontrollable factors and test conditions
- Selection of levels of controllable and uncontrollable factors
- Calculate the total degree of freedom
- Select appropriate orthogonal array
- Assignment of factors to column
- Execution of experiments according to the trial conditions in array
- Analyze the result
- Confirmation results.

The process parameters chosen for the experiments are: (a) peak current (*I*p), (b) pulse-on time (T_{on}) and (c) pulse-off time (T_{off}) while the response functions are: (a) material removal rate (MRR) (b)tool wear rate (TWR) and surface roughness(SR). According to the capability of the commercial EDM machine available and general recommendations of machining conditions for AISI 4340 the range and the number of levels of the parameters are selected as given in Table1:

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Table1:Process Parameters and Levels

S.No.	**Parameters**	**Units**	**Level 1**	**Level 2**	**Level 3**
1	Peak Current (I_p)	A	3	6	9
2	Pulse-on-time (T_{on})	µsec	15	20	30
3	Pulse-off-time (T_{off})	µsec	25	45	60

The experimental layout for the machining parameters using the Taguchi L9 orthogonal array is shown in Table 2

Table2 : Taguchi L9 Orthogonal Array (levels value of factors)

Exp. No.	**Peak Current (I_p in A)**	**Pulse on Time (T_{on} in µsec)**	**Pulse off Time (T_{off} in µsec)**
1	3	15.0	25
2	3	20.0	45
3	3	30.0	60
4	6	15.0	45
5	6	20.0	60
6	6	30.0	25
7	9	15.0	60
8	9	20.0	25
9	9	30.0	45

D. EXPERIMENTAL PROCEDURE:

Experiments are performed, randomly, according to the L9 orthogonal array, on a AISI 4340 of 5 mm thickness and 10 mm diameter. For each experiment a separate electrode is used. The depth of machining is set at 0.5mm for all experiments. The machining time is noted from the timer of the machine. The material removal rate and tool wear rate in mm^3/min is calculated by

$$\frac{\text{(Work piece/tool mass loss (gm))} * 1000}{\text{Density (gm/cc)} * \text{Machining Time}}$$

The surface roughness is measured by TR-200 is a portable surface roughness tester having least count 0.001 µm.

Figure 2:TR200 Surface Roughness Tester With Work Piece

The experimental results for MRR,TWR and SR based on L9 orthogonal array is shown in table 3.

Table3. Experimental results for MRR, TWR and SR

Exp.no	**MRR(mm^3/min)**	**TWR(mm^3/min)**	**SR(μm)**
1	0.3308	0.1449	1.669
2	0.2784	0.1219	3.041
3	0.2591	0.1135	5.720
4	0.4632	0.2029	3.970
5	0.3480	0.1524	4.250
6	0.8088	0.3543	6.120
7	0.6369	0.2790	3.110
8	1.6652	0.7294	6.780
9	1.6985	0.7440	7.030

III. RESULTS AND DISCUSSION

After the experimental procedure, different response factors like MRR, TWR and SR were calculated from the observed data. Then a statistical analysis were performed on the calculated values and the signal to noise ratio values of three response factors are tabulated in table 4.

Table 4. Signal to noise ratio for various response factors

Exp.no	**S/N Ratio for MRR**	**S/N Ratio for TWR**	**S/N Ratio for SR**
1	-9.6087	16.7786	-4.4491
2	-11.1066	18.2799	-9.6603
3	-11.7307	18.9001	-15.1479
4	-6.6846	13.8544	-11.9758
5	-9.1684	16.3403	-12.7350
6	-1.8432	9.0126	-15.7350
7	-3.9186	11.0879	-9.8552
8	4.4293	2.7407	-16.6246
9	4.6013	2.5685	-16.9391

ISSN 2348 – 8034
Impact Factor- 5.070

A. Material Removal Rate:

According to signal to noise ratio for MRR is shown in table 4, corresponding mean S/N ratio and analysis variances (ANOVA) is shown in table 5 and 6 respectively. For MRR, the calculation of S/N ratio follows "Larger the better model".

Table 5. Response table for signal-to- noise ratio for MRR.

Level	**Current (A)**	**Pulse on Time(µsec)**	**Pulse off Time(µsec)**
1	-10.815	-6.737	-2.341
2	-5.899	-5.282	-4.397
3	1.704	-2.991	-8.273
Delta	12.519	3.746	5.932
Rank	**1**	**3**	**2**

Table 6:ANOVA of MRR

Source	**DOF**	**SS**	**Adj MS**	**F Value**	**Contribution**
Current		1.78262	0.89131	18.51	5.73%
Pulse on Time		0.030553	0.15277	3.17	.30%
Pulse off Time		0.44442	0.22221	4.61	8.88%
Error		0.09632	0.4816		.09%
Total		2.35391			00%

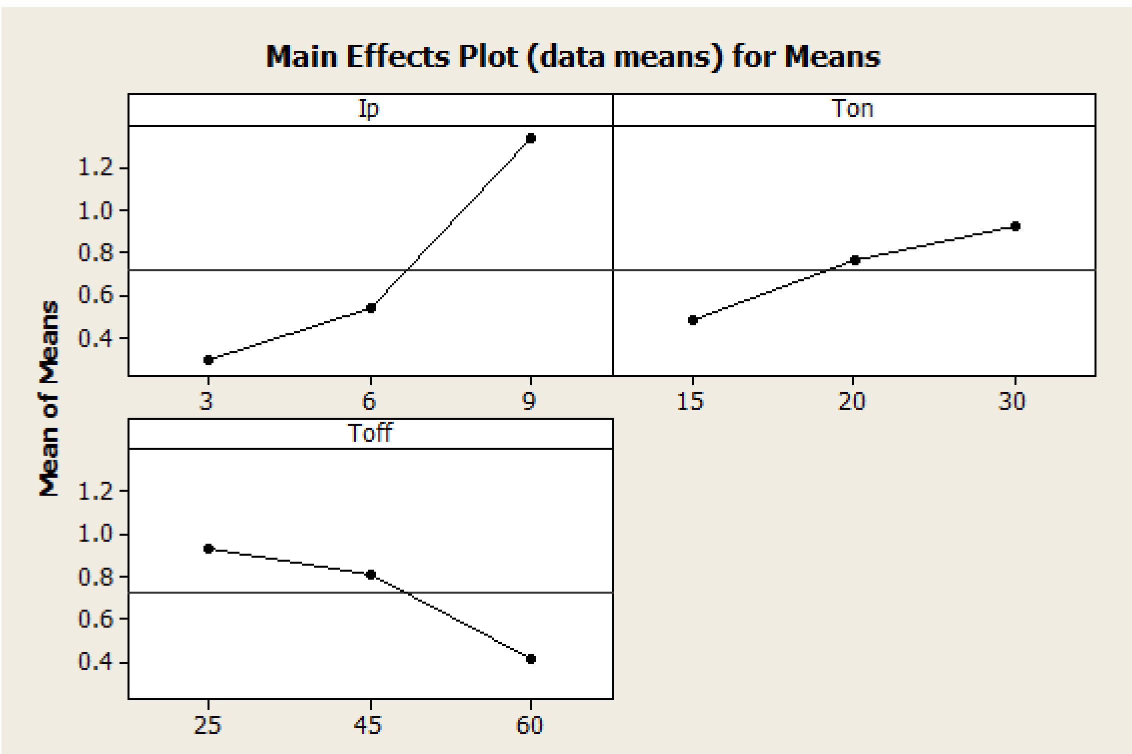

Figure 3:Main effect plot for MRR

B. Tool Wear Rate:

According to signal-to-noise ratio for tool wear rate (TWR) is shown in table 4, corresponding mean S/N ratio and analysis variances (ANOVA) is shown in table 7 and 8 respectively. For tool wear rate (TWR),the calculation of S/N ratio follows "Smaller the Better" model.

Table 7. Response table for signal-to- noise ratio for TWR

Level	Current	Pulse on time	Pulse off time
1	17.986	13.907	9.511
2	13.069	12.454	11.568
3	5.466	10.160	15.443
Delta	12.520	3.747	5.932
Rank	**1**	**3**	**2**

Table 8:ANOVA of TWR

Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	0.342059	0.171029	18.51	67.81%
Pulse on Time	2	0.058620	0.029310	3.17	11.62%
Pulse off Time	2	0.085273	0.042636	4.61	16.90%
Error	2	0.018480	0.009240		3.66%
Total	8	0.50443			100%

ISSN 2348 – 8034
Impact Factor- 5.070

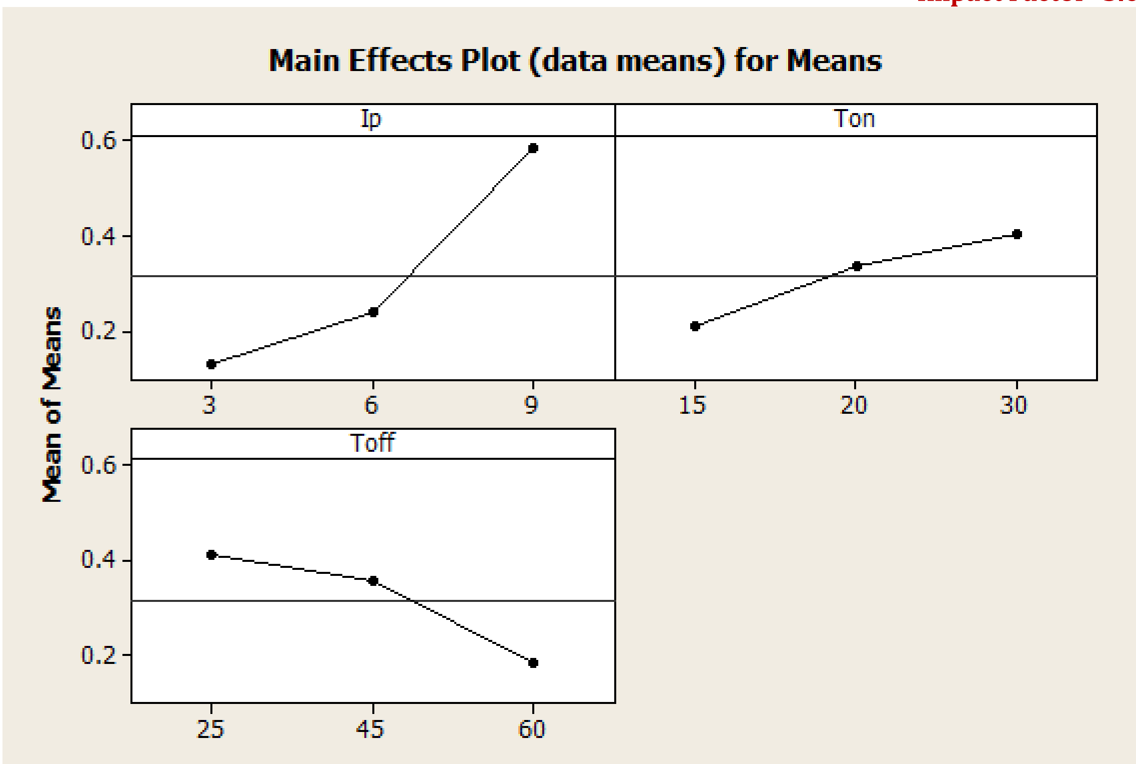

Figure 4:Main effect plot for TWR

A. Surface Roughness(SR):

According to signal-to-noise ratio for surface roughness(SR) is shown in table 4,corresponding mean S/N ratio and analysis variances (ANOVA) is shown in table 9 and 10 respectively. For tool wear rate (TWR),the calculation of S/N ratio follows "Smaller the Better" model.

Table 9. Response table for signal-to- noise ratio for SR

Level	Peak Current (A)	Pulse on Time(µsec)	Pulse off Time(µsec)
1	-9.752	-8.760	-12.270
2	-13.426	-12.951	-12.858
3	-14.473	-15.941	-12.524
Delta	4.721	7.181	0.589
Rank	**2**	**1**	**3**

Table 10:ANOVA of SR

Source	DOF	SS	Adj MS	F Value	Contribution
Current		7.118	3.559	2.10	5.45%
Pulse on Time		17.088	8.544	5.04	1.09%
Pulse off Time		0.380	0.190	0.11	.36%
Error		3.3888	1.694		2.11%
Total		27.973			

ISSN 2348 – 8034
Impact Factor- 5.070

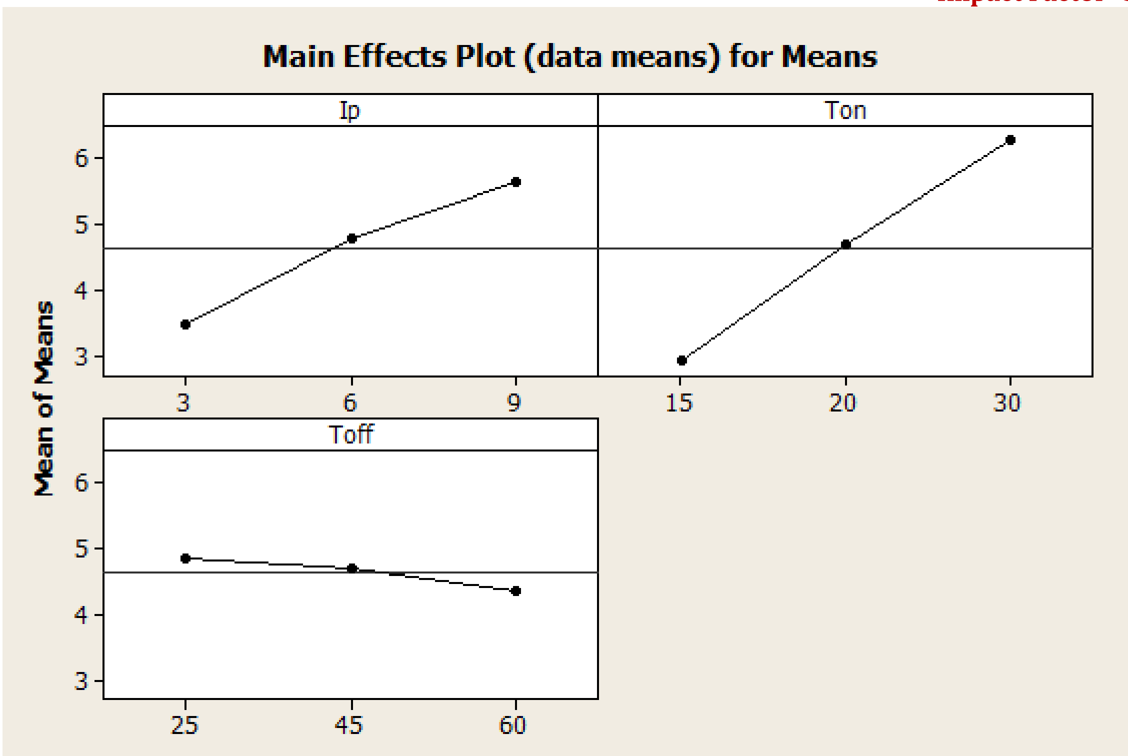

Figure 5:Main effect plot for SR

B. Confirmation test:

Confirmation tests have been performed for MRR, TWR and Surface Roughness with their optimum levels of process variables.

Table 11:Confirmation of Expected and Actual Values of MRR

periment No.	Optimum Machining Parameters			MRR	
	(A)	μsec)	T_{off} (μsec)	Actual	Expected
	9	30	25	.8734	931
				rror (%)	05

Table 12:Confirmation of Expected and Actual Values of TWR

periment No.	Optimum Machining Parameters			TWR	
	(A)	μsec)	T_{off} (μsec)	Actual	Expected
	3	15	60	0.0918	09503
				rror (%)	39

Table 13: Confirmation of Expected and Actual Values of Surface Roughness

pirement No.	**Optimum Machining Parameters**			**Surface Roughness**	
	(A)	**µsec)**	**T_{off} (µsec)**	**ctual**	**xpected**
	3	15	60	.502	72
				ror (%)	56

IV. CONCLUSION

- The material removal rate (MRR) is mainly affected by peak current (I_p). Pulse off time (T_{off}) has considerable effect on MRR. The effect of pulse on time (T_{on}) on MRR is negligible.
- Tool wear rate is mainly influenced by peak current (Ip) and pulse off time (T_{off}).Pulse on time (T_{on}) has very less effect on tool wear rate.
- Pulse on time (T_{on}) has maximum effect on surface roughness(SR).Peak current (I_p) has considerable effect on surface roughness.Pulse off time (T_{on}) has negligible effect on SR.
- 4) The optimum parameter can be considered for which maximum material removal rate, minimum tool wear rate and surface roughness is obtained.

Table 14: Optimum Parameters

Physical Requirement	**Optimum Machining Parameters**		
	I_p(A)	**T_{on}(µsec)**	**T_{off} (µsec)**
Maximum MRR	9	30	25
Minimum TWR	3	15	60
Minimum SR	3	15	60

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