



OPTIMIZATION OF EDM PARAMETERS USING TAGUCHI METHOD FOR STAINLESS STEEL 304

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Cite This Article: K. Sathish Kumar, Dr. N. Natarajan, Dr. T. Thirumalai & D. Karthick, "Optimization of EDM Parameters Using Taguchi Method for Stainless Steel 304", International Journal of Advanced Trends in Engineering and Technology, Special Issue, January, Page Number 121-127, 2018.

Abstract:

The present work aims to investigate the influence of process parameters such as Current, Pulse on time and Pulse off time on performance measures namely, surface roughness, Material Removal Rate, tool wear rate and Wear ratio during electrical discharge machining of stainless steel 304. Taguchi methodology has been employed for planning experiments and to obtain optimal combination of parameters using signal to noise ratios. Experimental results reveal that the contribution of Input parameters to Metal Removal Rate, Tool Wear Rate, and Wear Ratio. In addition the experiment data are transferred to signal to noise ratio are assessed by the analysis of variance. This analysis investigates the change in the solutions resulting from making changes in parameters of the Taguchi Method and this Analysis helps to find out the most significant parameters for Metal Removal Rate, Tool Wear Rate, and Wear Ratio separately.

Key Words: Electrical Discharge Machining, Roughness, Material Removal Rate, Tool Wear Rate, Optimization MINITAB 17

1. Introduction:

Electrical Discharge Machining (EDM) was not completely in use benefit of this method until 1943. When established up how the erosive properties of the method could be employed and make use of machining functions. Once that one was discovered by Joseph Priestly in 1770, In the middle of 1980s machining process on EDM were converted to a production instrument. Effective movement through EDM makes it more commonly offered and also engaging above outdated machining procedures. At starting days EDM process was actually inaccurate plus damaged using letdowns. Commercially established in the mid-1970s, the wire EDM machining originated to be a feasible practice that facilitated to run-through the metallic operational industry we have seen nowadays. Nowadays innovative changes in the area of non-traditional machining process are not to be considered as replacements for conventional machining methods of metal working. They also do not offer the best alternative solutions for all machining applications. The traditional metal cutting processes utilize shearing action on the work piece for material removal. However, the non-traditional processes depend on other factors such as chemical properties, melting and vaporization of the material, electrolytic displacement of ions and mechanical erosion. The main reasons for using the non-traditional machining processes are to machine high strength alloys, complex surfaces, difficult geometries, high accuracies surface finish and automation requirements. Electrical Discharge Machining is a most basic nontraditional machining process, where material is removed by thermal energy of spark occurring by means of repeated sequences of electrical ejections between the small gap of an electrode and a work piece. EDM process is removing undesirable material in the form of debris and produce shape of the tool surface as of a metal portion by means of a recurring electrical ejection stuck between tool i.e. cathode and the work piece i.e. anode material in the existence of dielectric liquid. In this machining process work piece is called the anode because it is connected with positive terminal and electrode is connected with negative terminal i.e. called cathode. Dielectric fluid may be kerosene, transformer oil, distilled water, etc

2. Principle of EDM:



Figure 1

In this machining method the metallic particle is removed as of the work piece owed to controlled wearing away action by means of repeatedly occurring spark ejection with the help of discharge current applied by power supply taking place in small gap in the range of 10 –125 μm between the tool and work piece. The below schematic fig. 1 shows that the mechanical as well as electrical control system and electrical path for Electric Discharge Machining. The tool is attached to cathode terminal and the

work piece is attached to anode terminal. After the potential differences apply by power supply crossways the small gap develops adequately high electrical discharges through the small break in the form of the spark in interval of 10 of micro seconds. Then the electron ions are present accelerated towards the positive ions, bringing on a discharge passage that turn out to be conductive.

3. Selection of Work Materials:

Using 304 stainless steel is a smart choice for your budget's project and longevity. It is cost-effective in comparison to other materials. Its high quality and durability ensures that your product lasts a long time and the design of it is suitable for home and commercial use. Stainless steel with excellent corrosion resistance and good resistance to intergranular corrosion. Of oxidizing acids, such as concentration $\leq 65\%$ below the boiling temperature of nitric acid, with strong corrosion resistance. Most of the alkali solution and organic acids and inorganic acids also has good corrosion resistance Excellent hot and cold forming process and performance. Can processing board, tube, wire, tape, type of product, for the manufacture of cold heading, deep drawing, deep drawing forming parts. Better low temperature performance. At -180°C condition, strength, elongation, area reduction rate is very good. In the absence of brittle transition temperature, often used at low temperatures. Has good weldability. Welding method can be used often, both before welding without heat treatment after welding.

4. Selection of Tool Material:

In this experiment Copper rod of $12.5 \times 25 \text{ mm}^2$ used. Copper products are famous for their heat resistance, toughness and good machinability. One of the products of Copper are the solid Copper rods that are used for cutting dissimilar alloys, cast iron, stainless steel, refractory alloy steel, nickel based alloy, titanium alloy and other nonferrous metals. The solid Copper rods are offered as a ground and unground with metric or inch standards. These rods possess the features of good wear resistance and corrosion resistance. The other uses of these rods are as HSS cutting tool, carbide end mills, aerospace cutting tool, carbide drills, milling cutter, electronic cutter, gun barrel, metal cutting saw and several other.

5. Experimental Procedure:

To start machining having discussion of an investigational work designed earlier just before the implementation of machining. This one concerns a L9 orthogonal array by using design of experiments from Taguchi's method, choice of work piece, selection of tool, investigational set-up then by using the data of experiments calculation made for Material Removal Rate (MRR), Tool wear Rate (TWR), Wear ratio (WR) and Surface Roughness (SR).

6. Investigational Set Up:

The experimentations be there performed by operating on Electric Discharge Machine classified as (die-sinking type) ELECTRONICA -EMS 5030 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. The EDM machine contains with the following measures for our experimentation. For circulation of dielectric there is reservoir at base, pump for passage.

Table 1: Control Parameters on EMS 5030 EDM Machine

S.No	Control parameters	Minimum	Maximam
1	Current (IA)	10	50
2	Pulse on time (μs)	1	99
3	Pulse off time (μs)	1	9
4	Peak voltage	30	250



Figure 2



Figure 3

Die Sinker EDM Machine Setup with Tool And Work Piece (Model: Electronica – EMS 5030)

Table 2: Chemical composition of stainless steel 304

Element	Percentage (%)	Specifications (AISI304)
C	0.078	0.08Max
Mn	1.389	2.00Max
Si	0.328	1.00Max
P	0.033	0.045Max
S	0.008	0.030Max
Cr	18.072	18.00-20.00
Ni	8.163	8.00-10.50

7. Surface Roughness Test:

Surface Roughness is the size of the surface texture. It is expressed in μm and denoted by Ra. If the value comes higher that means the surface is rough and if lower comes that means that the surface is smooth. The surface roughness values are measured by means of an apparatus portable type profilometer, mitutoyo (Model: Model surf Test SJ-312) shown in fig.3.4. After measurement calculate by arithmetic mean of three data is in use as the absolute value.



Figure 4: Surface roughness measuring machine, Model surf Test SJ-312

8. Result & Discussion:

In this chapter, we are discussing about the effects or influence of machining parameter, i.e. Discharge current, Pulse on time and Pulse off time on material removal rate (MRR), surface roughness (Ra) of Stainless Steel 304 machined work piece with Copper tool and find out which parameter is most important during an experiment with the help of Taguchi design & Multi objective genetic algorithm using MATLAB. Surface roughness, Metal removal Rate, Tool wear ratio and their responsive S/N Ratio, Mean should be tabulated below

Table 3: S/N Ratio and Mean for TWR & WR

S.No	Current	Ton	Toff	MRR	TWR	WR
1	10	10	1	0.724	6.063	5.997
2	27.49	10	1	1.3574	5.753	3.627
3	29.3	89.392	4.531	5.438	8.227	-1.289
4	29.87	19.186	3.099	2.4761	6.8367	2.4286
5	29.3	75.285	4.531	4.9336	8.0925	-0.5841
6	27.49	28.04	1	1.9996	5.9264	2.7256
7	27.49	75.285	1	3.6816	6.38	0.3634
8	27.49	89.392	1	4.1838	6.5154	-0.341
9	29.87	89.392	3.0999	4.9751	7.5107	-1.0816
10	21.49	10	1	1.1401	5.8595	4.4405
11	29.3	89.392	4.5314	5.4358	8.2279	-1.2894
12	21.49	75.285	1	3.4642	6.4862	1.1762
13	10	10	1	0.724	6.063	5.997

9. Taguchi Optimization:

Taguchi method is systematic and efficiency approach to find the optimal combination of input parameters. This method utilizes the orthogonal array of experiments to reduce the number of experiments in any machining process. Since four input parameters have been selected, L9 orthogonal array has been selected for this study. Using the orthogonal array 9 experiments has been conducted with each of 2 replicates.

Taguchi Design Experiments in MINITAB 17:

MINITAB 15 offers many possible ways in which an experiment can be carried out. A number of ordinary orthogonal arrays have been created to ease of experimental design. For each of these arrays can be used to design experiments to suit numerous experimental situations. A number of orthogonal arrays, such as L4, L8, L9, L12, L16, L18, and L27 and so on, created for two or three level factors. MINITAB 17 estimates response tables and creates main effects and S/N ratios plans intended It is also used to study the effects of input parameters on response. There are 3 signal to noise ratios of common interest optimization of static problems

✓ Smaller the better

$$n = -10 \log_{10} [\text{mean of sum of squares of measured data}]$$

The generic form of S/N ratio then becomes

$$S/N_{LB1} = -10 \log (1/3 * (m_1^2 + m_2^2 + m_3^2))$$

✓ Larger the better

$$n = -10 \log_{10} [\text{mean of sum of squares of reciprocal measured data}]$$

The generic form of S/N ratio then becomes

$$S/N_{LB1} = -10 \log (1/Y^2)$$

Manual Calculation on Surface Roughness (Ra):

For Trail No 1

$$S/N_{LB1} = -10 \log (1/3 * (5.384^2 + 5.386^2 + 5.388^2))$$

$$S/N_{LB1} = -10 \log 29$$

$$S/N_{LB1} = -14.623$$

For Trail No 2

$$S/N_{LB2} = -17.5646$$

For Trail No 3

$$S/N_{LB3} = -19.8331$$

For Trail No 4

$$S/N_{LB4} = -17.1775$$

For Trail No 5

$$S/N_{LB5} = -19.0730$$

For Trail No 6

$$S/N_{LB6} = -13.3825$$

For Trail No 7

$$S/N_{LB7} = -15.773$$

For Trail No 8

$$S/N_{LB8} = -19.0449$$

For Trail No 9

$$S/N_{LB9} = -16.3678$$

Main Effect of Current on surface roughness (Ra):

$$\text{Level 1} = (S/N_{LB1} + S/N_{LB2} + S/N_{LB3}) / 3$$

$$= (-14.623 - 17.564 - 19.8331) / 3$$

$$= -17.34$$

$$\text{Level 2} = (-17.775 - 19.0730 - 13.3525) / 3 = -16.74$$

$$\text{Level 3} = (-15.773 - 19.0449 - 16.3678) / 3$$

$$= -17.06$$

$$\text{Regression equation of WR} = 8.05 - 0.1354 A - 0.0500$$

$$B - 0.199 C$$

In Material Removal Rate (MRR) Calculation “Larger the Better”, Tool Wear Rate (TWR) Calculation “Smaller the Better”, Wear Ratio (WR) Calculation “Smaller the Better” so that the required value should be take and it’s as a most responsive parameters in this optimizing parameters using Taguchi method

Table 3.4: Analysis of Variance for Ra Taguchi Analysis using Minitab

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	0.585	0.585	0.293	0.06	0.945
B	2	7.829	7.829	3.915	0.78	0.561
C	2	5.949	5.949	2.974	0.59	0.627
Error	2	10.019	10.019	5.009		
Total	8	24.382				

Taguchi Analysis Ra versus I_A , T_{on} , T_{off}

Smaller is better

Table 4.2: Response Table for Means

Level	IA	Ton	Toff
1	7.584	6.253	6.338
2	6.961	8.501	7.122
3	7.230	7.021	8.315
Delta	0.623	2.247	1.977
Rank	3	1	2

Level	IA	Ton	Toff
1	-17.34	-15.86	-15.68
2	-16.55	-18.56	-17.04
3	-17.06	-16.53	-18.23
delta	0.80	2.70	2.54
rank	3	2	1

Regression equation is $Ra = 5.65 - 0.0177 A + 0.0096 B + 0.494 C$

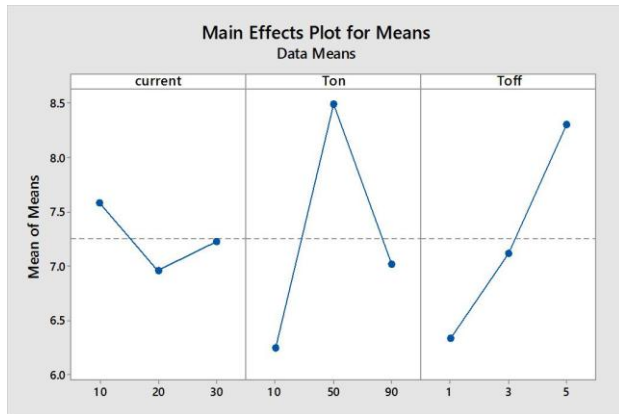


Figure 4.1: Main Effects Plot for SN ratio

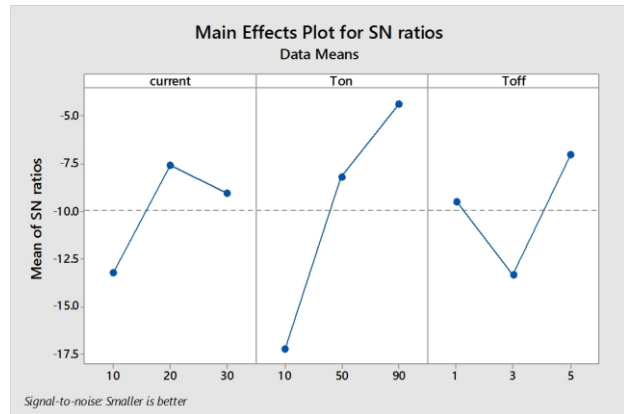


Figure 4.2: Main Effects Plot for Mean

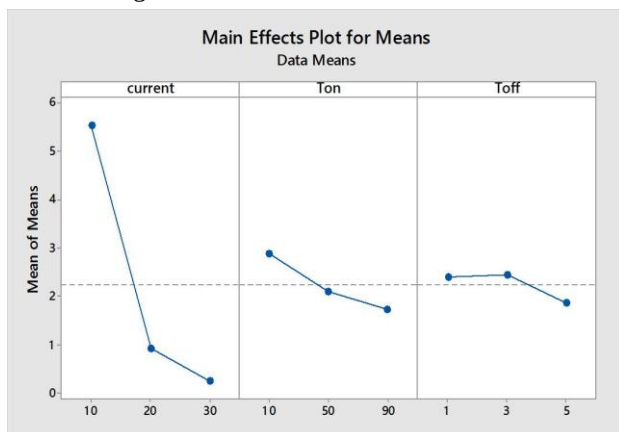


Figure 4.3: Main Effects Plot for SN ratios

Table 4.3: S/N Ratio and Mean for Ra & MRR

Level	Ra	S/N Ratio	MEAN	MRR	S/N Ratio	MEAN
1	5.386	-14.625	5.386	1.529	14.62533	5.386
2	7.555	-17.564	7.555	1.354	17.56469	7.555
3	9.81	-19.833	9.81	4.878	19.83338	9.81
4	7.226	-17.178	7.226	1.287	17.17796	7.226
5	8.988	-19.073	8.988	5.844	19.07326	8.988
6	4.669	-13.384	4.669	4.99	13.38448	4.669
7	6.148	-15.774	6.148	3.468	15.77468	6.148
8	8.959	-19.045	8.959	3.637	19.04519	8.959
9	6.584	-16.369	6.584	4.96	16.3698	6.584

Percentage of Contribution:

The below table delivers that the percentage of contribution that means Influencing various parameters to Ra, MRR, TWR and WR

Table 4.4: Percentage of Contribution

Parameters	Ra	MRR	TWR	WR
Current	38.24%	50.74%	25.4%	20.08%
Pulse on Time	30.74%	43.70%	43.54%	33.20%
Pulse off Time	30.15%	2.74%	30.96%	44%
Other Defects	0.87%	2.81%	0.10%	2.72%

Level	TWR	S/N Ratio	MEAN	WR	S/N Ratio	MEAN
1	7.44	-17.431	7.44	6.531	-16.30	6.531
2	7.28	-17.253	7.289	5.383	-14.62	5.383
3	1.76	-4.9151	1.761	4.672	-13.39	4.672
4	8.40	-18.491	8.406	1.786	5.0390	1.78
5	1.03	-0.298	1.035	0.623	4.1102	0.623
6	1.56	-3.862	1.56	0.361	8.849	0.361
7	6.19	-15.840	6.195	0.326	9.7196	0.326
8	2.26	-7.105	2.266	0.312	10.100	0.316

9	1.62	-4.195	1.621	0.177	15.035	0.171
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Figure 4.4: Work Piece after Machining



Figure 4.5: Tool after Machining

10. Conclusion:

In this Investigation on EDM to know the effect of machining material removal rate and surface roughness of the Stainless steel 304 work piece using Copper. Both these outputs are important in industrial applications. The conduction of experiment depends upon various parameters settings such as discharge current (I_A), pulse on time (T_{on}) and pulse off time (T_{off}) have been selected. Based on L9 orthogonal array by Taguchi design was conducted and MINITAB 17 software package was used for analysis of the experiment. To find out the most suitable machining parameters. From the results of Parameters affect nearest equally affect R_a , In MRR we conclude that the Current and Pulse off time is most significant factor MRR and increased slightly with changes of pulse off time. From the results of TWR, WR we conclude that the pulse on time and pulse off time is most significant or influencing factor then pulse on time. TWR, WR increased and increased slightly with changes of Current From the results of multi objective optimization we conclude most significant or influencing factor current is 10A pulse on time 10 μ s pulse off time 1 μ s.

- ✓ Most significant factor for MRR is 10A, 10 μ s, 1 μ s.
- ✓ Most significant factor for TWR is 20A, 10 μ s, 1 μ s.
- ✓ Most significant factor for WR is 27A, 75 μ s, 3 μ s

11. References:

1. N. Natarajan, P. Suresh, "Experimental investigations on the microhole machining of 304 stainless steel by micro-EDM process using RC-type pulse generator", The International Journal of Advanced Manufacturing Technology, Vol. 77, No. 9-12, 2015, pp. 1741-1750.
2. M. Boujelbene, E. Bayraktar, W. Tebni and S. Ben Salem, Influence of machining parameters on the surface integrity in electrical discharge machining, Arch. Mater. Sci. Eng., 37, (2009) 110-116.
3. N. Natarajan, R.M. Arunachalam, R. Thanigaivelan, "Experimental study and analysis of micro holes machining in EDM of SS 304", International Journal of Machining and Machinability of Materials, Vol. 13, No. 1, pp. 1-16, 2013.
4. Liu HS, Yan BH, Huang FY, Qiu KH (2005) A study on the characterization of high nickel alloy micro-holes using micro-EDM and their applications. J Mater Process Technol 169:418-426
5. Han F, Wachi S, Kunieda M (2004) Improvement of machining characteristics of micro-EDM using transistor type isopulse generator and servo feed control. Precis Eng 28:378-385
6. Amorim F L, Weingaertner WL (2005) The influence of generator actuation mode and process parameters on the performance of finish EDM of a tool steel. J Mater Process Technol 166:411-416
7. Liao YS, Huang JT, Chen YH (2004) A study to achieve a fine surface finish in wire-EDM. J Mater Process Technol 149:165-171
8. Marafona J (2007) Black layer characterisation and electrode wear ratio in electrical discharge machining (EDM). J Mater Process Technol 184:27-
9. Nguyen MD, Rahman M, Wong YS (2012) An experimental study on micro-EDM in low-resistivity deionized water using short voltage pulses. Int J Adv Manuf Technol 58:533-544
10. N. Natarajan, R.M. Arunachalam, "Optimization of micro-EDM with multiple performance characteristics using Taguchi method and Grey relational Analysis", Journal of Scientific & Industrial Research, Vol. 70, July 2011, pp. 500-505.
11. Jahan, M.P., Wong, Y.S. and Rahman, M. (2010) 'A comparative experimental investigation of deep-hole micro-EDM drilling capability for cemented carbide (WC-Co) against austenitic stainless steel (SUS 304)', The International Journal of Advanced Manufacturing Technology, Vol. 46, No. 9, pp. 1145-1160.
12. Jung, J.H. and Kwon, W.T. (2010) 'Optimization of EDM process for multiple performance characteristics using Taguchi method and Grey relational analysis', Journal of Mechanical Science and Technology, Vol. 24, No. 5, pp. 1083-1090.
13. Kansal, H.K., Singh, S. and Kumar, P. (2005) 'Application of Taguchi method for optimisation of powder mixed electrical discharge machining', International Journal of Manufacturing Technology and Management, Vol. 7, Nos. 2/3/4, pp. 329-341.

14. Kibria, G., Sarkar, B.R., Pradhan, B.B. and Bhattacharyya, B. (2010) 'Comparative study of different dielectrics for micro-EDM performance during microhole machining of Ti-6Al-4V alloy', The International Journal of Advanced Manufacturing Technology, Vol. 47, No. 5, pp.11–19.
15. H.K. Kansal, Sehijpal Singh, Pradeep Kumar, Numerical simulation of powder mixed electric discharge machining (PMEDM) using finite element method, Math. Comp. Model., 47 (2008) 1217-1237.
16. C.J. Luis, "A study of optimization of machining parameters for electrical discharge machining of boron carbide", Materials and Manufacturing Processes, 19(6), 1041-1070.
17. Sushil Kumar Choudhary, Current Advanced Research Development of Electric Discharge Machining (EDM): A Review", International Journal of Research in Advent Technology, Vol.2, No.3, March 2014.
18. Dhanasekaran, R, Senthil Kumar, P, Baskaran, S and Santhi, K, "Wear behavior of surface treated alloy steel with assorted blends of fine particles by using plasma spray process", Advanced Materials Research, Vol. 383-390, pp. 893-897, 2012
19. O.A. Abu Zeid, On the effect of electro-discharge machining parameters on the fatigue life of AISI D6 tool steel, J. Mater. Process. Technol., 68 (1997) 27-32.
20. A. A. Khan, Electrode wear and material removal rate during EDM of aluminum and mild steel using copper and brass electrodes, Int. J. Adv. Manuf. Technol., 39 (2008) 482-487
21. R. Thanigaivelan, RM. Arunachalam, N.Natarajan, "Study on Influence of Electrodes in Electric Discharge Machining", Recent Patents on Mechanical Engineering, Vol.8, No.2, 2015, pp. 161-167.
22. Masuzawa, T., Tanaka, K., Nakamura, Y. and Kinoshita, N. (1983) 'Water-based dielectric solution for EDM', CIRP Annals–Manufacturing Technology, Vol. 32, No. 1, pp.119–122.
23. Habib SS. Study of the parameters in electrical discharge machining through response surface methodology approach. App. Math. Model. 2009; 33: 4397-4407.
24. N. Natarajan, RM. Arunachalam, "Experimental Investigations and Optimization of Process Parameters in micro-EDM with Multiple Performance Characteristics", International Journal of Experimental Design and Process Optimisation, Vol.2, No.4, pp. 336-356, 2011.