

APPLICATION OF TAGUCHI APPROACH FOR OPTIMIZATION OF CNC WIRE ELECTRICAL DISCHARGE MACHINING PROCESS PARAMETERS

Bijendra Diwakar*

Vedansh Chaturvedi**

Jyoti Vimal**

ABSTRACT

*In this research work, through the Taguchi methodology found the optimum process parameters for CNC wire electric discharge machining (WEDM). The object of the research paper to optimize the MRR and SR of work piece high chromium high carbon (HCHC) die steel tool. This methodology based on Taguchi's, analysis of variance (ANOVA) and signal to noise ratio (S/N Ratio) to optimize the CNC WEDM process parameter. The design of experiment for machining process control parameter are Voltage(A), Discharge current(B), Pulse duration(C), Pulse frequency(D) and Wire Tension(E) L₂₇ (3*5) standard orthogonal array design of experiment three level and five parameter A, B,C,D and E respectively for each combination we have conducted one experiment. We have found the optimum results for CNC WEDM through the Signal to Noise ratio (S/N ratio).*

Keywords: CNC WEDM, Taguchi' method, ANOVA, MRR, SR , S/N Ratio.

*Research Scholar

**Assistant Professor, Department of Mechanical Engineering , Madhav Institute of Technology & Science, Gwalior

INTRODUCTION

The Wire-cut EDM (WEDM) uses a slender wire diameter of the order of 0.15 –0.30 mm as an Electrode. Wire travels through the work piece from upper and lower wire guides. In wire-cut EDM process the spark is occurring between continuous traveling wire and work piece. Here wire Acts like a band saw, but sparks instead of teeth do the cutting. The variations in the machining Parameters, such as the gap voltage, wire feed rate, gap current, and duty factor, greatly affect the Measures of the machining performance, for example, the SR and the MRR. Therefore, proper Selection of the machining parameters can result in better machining performance in the electrical Discharge machining process. In this study, a Reciprocating Wire-cut EDM machine, Electronica makes, EZZYCUT – PLUS model was used as the experimental machine. Cylindrical hard copper wire with a diameter of 0.25 mm was used as an electrode to erode a work piece of High-Carbon-High-Chromium (HCHC) die steel plate of the thickness of 30mm. The schematic diagram of the experimental setup is shown in Fig. 1. The work piece and electrode were separated by a moving dielectric fluid i.e. blend of tap water and coolant oil (S100) in a ratio of 20:1. The variation of MRR and SR with machining parameters and optimization of machining settings for maximum MRR minimum SR should be investigated experimentally and the obtained results should be interpreted and modelled statistically to understand closely the behaviour of machining rate and accuracy in CNC WEDM In this study, the effect of the machining parameters and their level of significance on the MRR and SR are statistically evaluated by using analysis of variance (ANOVA). The settings of machining parameters were determined by using Taguchi experimental design method.

METHODOLOGY

A. *Analysis of Variance (ANOVA)*

Analysis of variance (ANOVA) and F-test (standard analysis) are used to analysis the experimental data as given follows

Notation:

Following Notation are used for calculation of ANOVA method

C.F. = Correction factor

T = Total of all result

n = Total no. of experiments

S_T = Total sum of squares to total variation.

X_i = Value of results of each experiments ($i = 1$ to 27)

S_x = Sum of the squares of due to parameter x (X = A, B, C, D,E)

N_{X1}, N_{X2}, N_{X3} = Repeating number of each level (1, 2, 3) of parameter X

X_{X1}, X_{X2}, X_{X3} = Values of result of each level (1, 2, 3) of parameter X

F_x = Degree of freedom (D.O.F.) of parameter of X

f_T = Total degree of freedom (D.O.F.)

f_e = Degree of freedom (D.O.F.) of error terms

V_x = Variance of parameter X

S_e = Sum of square of error terms

V_e = Variance of error terms

F_x = F-ratio of parameter of X

S_x' = Pure sum of square

C_x = Percentage of contribution of parameter X

C_e = Percentage of contribution of error terms

$CF = T^2/n$

$S_T = \sum_{i=1 \text{ to } 27} X_i^2 - CF$

$S_x = (X_{X1}^2/N_{X1} + X_{X2}^2/N_{X2} + X_{X3}^2/N_{X3}) - CF$

$F_x = (\text{number of levels of parameter X}) - 1$

$f_T = (\text{total number of results}) - 1$

$f_e = f_T - \sum f_x$

$V_x = S_x/f_x$

$S_e = S_T - \sum S_x$

$V_e = S_e/f_e$

$F_x = V_x/V_e$

$S_x' = S_x - (V_e * f_e)$

$C_x = S_x'/S_T * 100\%$

$C_e = (1 - \sum P_x) * 100\%$

SIGNAL TO NOISE RATIO CALCULATION

Quality Characteristics:

S/N characteristics formulated for three different categories are as follows:

Larger is Best Characteristic:

Data sequence for MRR (Material Removal Rate), which are higher-the-better performance characteristic are pre-processed as per Eq.1

$S/N = -10 \log ((1/n) (\sum(1/x^2))) \dots \dots \dots 1$

Nominal and Smaller are Best Characteristics

Data sequences for SR, which are lower-the-better performance characteristic, are pre-processed as per Eq.1 &2

$$S/N = -10 \log (x/s^2x) \dots \dots \dots 2$$

$$S/N = -10 \log ((1/n) (\sum(x^2))) \dots \dots \dots 3$$

Where \hat{y} is average of observed data x , sx^2 is variance of x , and n is number of observations.

EXPERIMENTAL SET UP AND WORK PROCEDURE:

Equipment:

Wire Cut EDM works on the principle of Electrical Discharge Wire Cutting (EDWC), most commonly known as Wire Cut EDM. It is a spark erosion procedure to produce complex 2-Dimensional and 3-Dimensional shapes through electrically conductive work pieces. This machine is used only for manufacture parts which are electrically conductive. Wire Cut EDM differs from conventional EDM is that a thin, 0.05-0.3 mm in diameter wire used for manufacturing of our product.

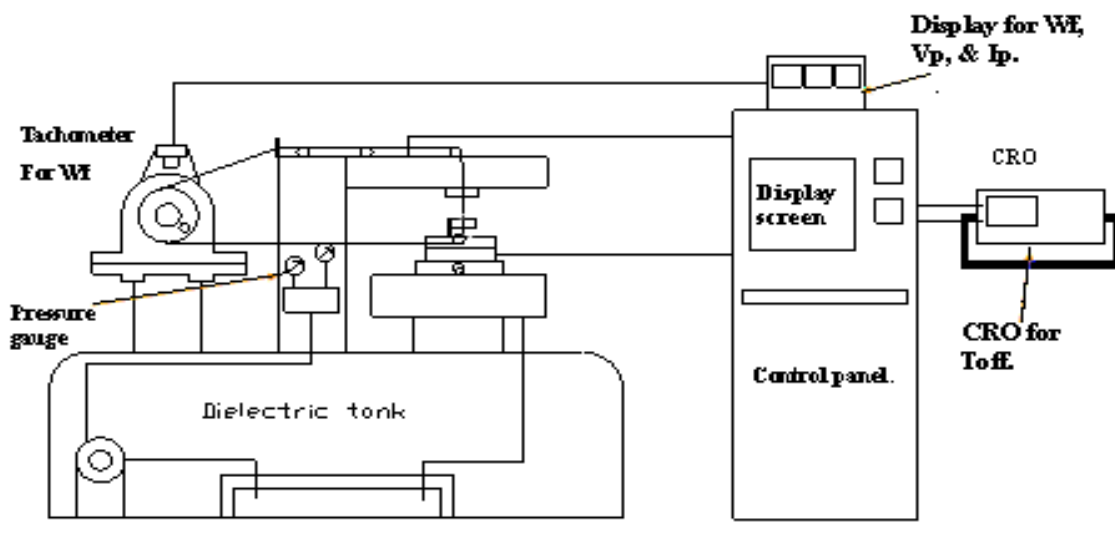


Figure 1. Schematic Diagram of EzeeCutPlus Wire EDM

Material:

In this investigation, we used work piece material High Chromium High Carbon die steel (HCHC) in this experiments. Which have cold work tool steel with substantial amounts of Chromium and Carbon (HCHC) tool steels offer good dimensional accuracy, wear resistance and machinability.

Design of Experiments

The experimental layout for the machining parameters using the L_{27} orthogonal array was used in this study. This array consists of five control parameters and three level, as shown in

table I In the taguchi method, most all of the observed values are calculated based on 'the higher the better' and 'the smaller the better'..Thus in this study, the observed values of MRR, and SR were set to maximum, and minimum respectively.

Table I: Design Scheme of Experiment of Parameters and Level

Control Parameters	Level			Units	Observed Values
	1	2	3		
Voltage [A]	120.00	140.00	160.00	Volt	1. Material Removal Rate (mm ³ /min) 2. Surface Roughness (Ra)
Discharge current [B]	16.00	24.00	32.00	Amp	
Pulse duration [C]	6.00	8.00	10.00	μsec	
Pulse frequency [D]	60.00	70.00	80.00	KHz	
Wire Tension [E]	1100.00	1200.00	1300.00	gm	

Table II: Observed Values of MRR and SR

Experimental trial	A	B	C	D	E	Response of MRR (mm ³ /min)	Response of SR(μm)
1	1	1	1	1	1	0.995	4.313
2	1	1	1	1	2	0.976	3.564
3	1	1	1	1	3	0.882	3.432
4	1	2	2	2	1	0.685	4.001
5	1	2	2	2	2	0.692	3.978
6	1	2	2	2	3	0.783	3.671
7	1	3	3	3	1	0.829	3.984
8	1	3	3	3	2	0.925	3.986
9	1	3	3	3	3	0.872	3.789
10	2	1	2	3	1	0.534	3.981
11	2	1	2	3	2	0.672	4.101
12	2	1	2	3	3	0.875	3.981

13	2	2	3	1	1	0.892	3.781
14	2	2	3	1	2	0.910	3.789
15	2	2	3	1	3	0.890	3.897
16	2	3	1	2	1	0.801	2.988
17	2	3	1	2	2	0.981	2.987
18	2	3	1	2	3	0.785	3.981
19	3	1	3	2	1	0.689	3.895
20	3	1	3	2	2	0.769	3.900
21	3	1	3	2	3	0.929	4.106
22	3	2	1	3	1	0.983	3.005
23	3	2	1	3	2	0.871	3.950
24	3	2	1	3	3	0.898	3.671
25	3	3	2	1	1	0.987	4.001
26	3	3	2	1	2	0.911	3.123
27	3	3	2	1	3	0.907	3.910

TAGUCHI ANALYSIS FOR MRR

Analysis of MRR using MINITAB software

Taguchi Analysis: Response of MRR versus A, B, C, D, E

Larger is better

Table III. Response Table for Signal to Noise Ratios for MRR

Level	A	B	C	D	E
1	-1.4944	-1.9515	-0.8694	-0.6600	-1.8696
2	-1.8980	-1.5240	-2.2713	-2.1069	-1.4239
3	-1.1346	-1.0515	-1.3863	-1.7600	-1.2335
Delta	0.7635	0.9000	1.4019	1.4469	0.6360

Rank	4	3	2	1	5
------	---	---	---	---	---

Table IV: Response Table for Means for MRR

Level	A	B	C	D	E
1	0.8488	0.8134	0.9080	0.9278	0.8217
2	0.8156	0.8449	0.7829	0.7904	0.8563
3	0.8827	0.8887	0.8561	0.8288	0.8690
Delta	0.0671	0.0752	0.1251	0.1373	0.0473
Rank	4	3	2	1	5

TAGUCHI ANALYSIS FOR SR

Taguchi Analysis: Response of SR versus A, B, C, D, E

Smaller is better

Table V. Response Table for Signal to Noise Ratios For SR

Level	A	B	C	D	E
1	-11.71	-11.84	-10.92	-11.46	-11.47
2	-11.36	-11.45	-11.71	-11.36	-11.34
3	-11.38	-11.15	-11.82	-11.63	-11.64
Delta	0.35	0.69	0.91	0.27	0.31
Rank	3	2	1	5	4

Table VI. Response Table for Means for SR

Level	A	B	C	D	E
1	3.858	3.919	3.543	3.757	3.772

2	3.721	3.749	3.861	3.723	3.709
3	3.729	3.639	3.903	3.828	3.826
Delta	0.137	0.280	0.360	0.105	0.118
Rank	3	2	1	5	4

Result and Discussion:-

The following discussion focuses on the different of process parameters to the observed values (MRR and SR) based on the Taguchi methodology.

Material Removal Rate (MRR)

Main effects of MRR of each factor for various level conditions are shown in figure2 and 3.

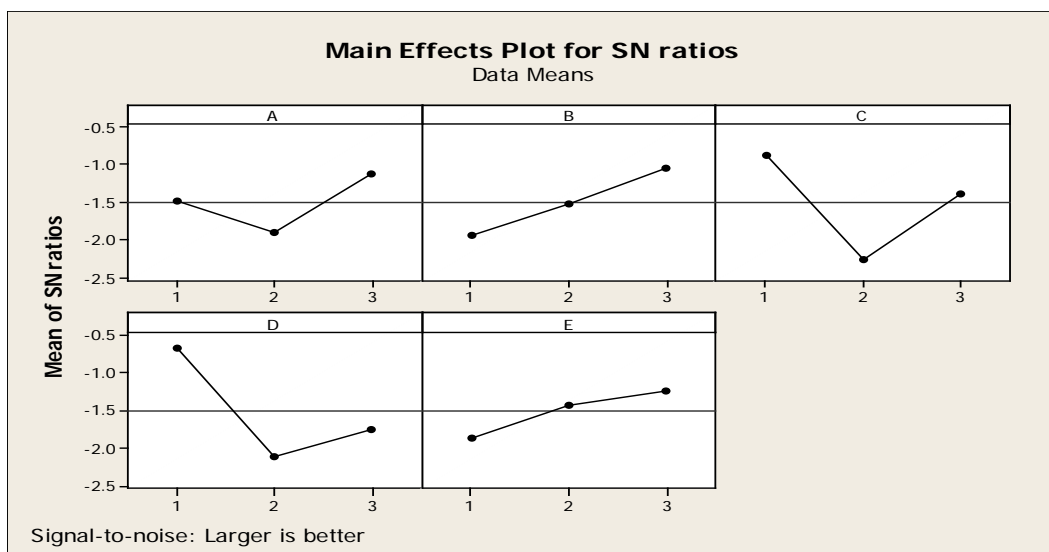


Fig.2 Main Effects Plot for S/N ratios for MRR

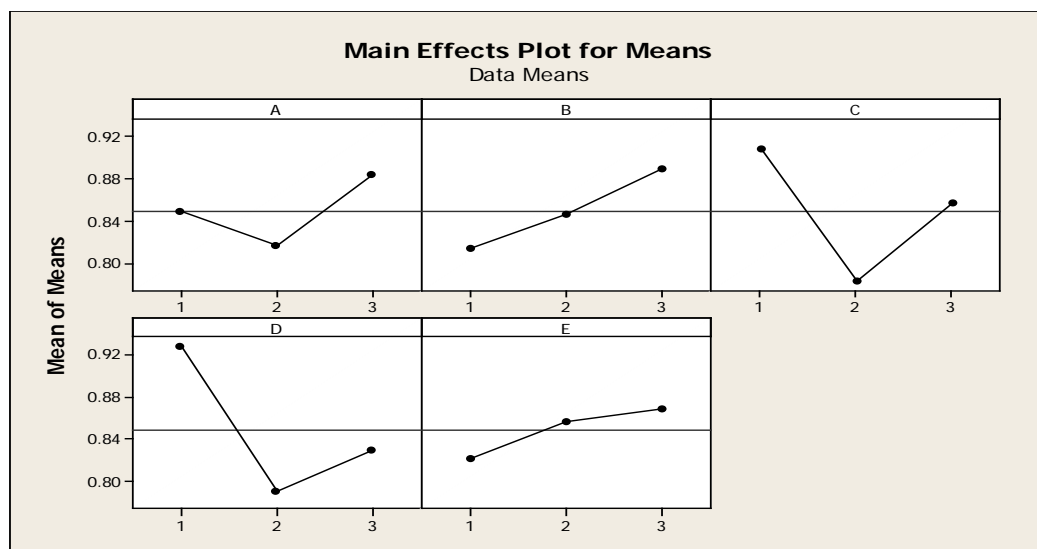


Fig. 3 Main Effects Plot for Means for MRR

With the above graph for S/N ratio for MRR and Mean for MRR we have found the optimal parameter setting A3B3C1D1E3 which is voltage at level 3 (160 Volt), Discharge current at level 3 (32 Amp), Pulse duration at level 1 (6 μ sec), pulse frequency at level 1 (60 KHz), Wire tension at level 3 (1300 gm).

Surface Roughness (SR)

Figure 4 and 5 evaluates the main effects of each factor for various level conditions.

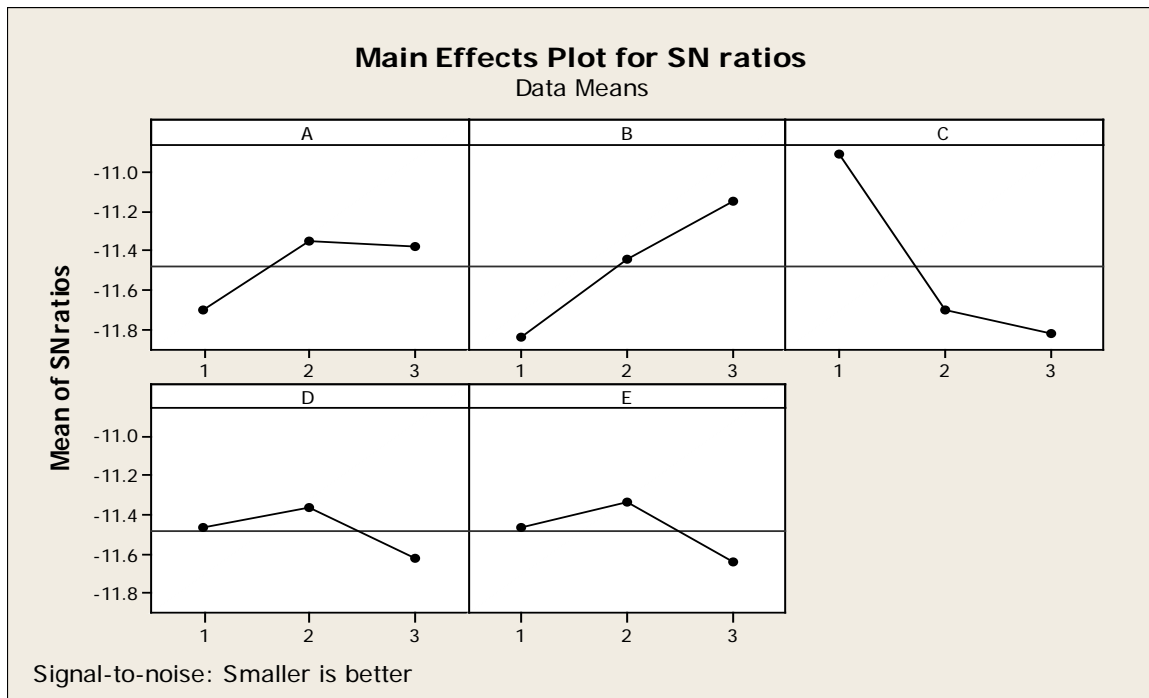


Fig . 4 Main Effects Plot for S/N ratios for SR

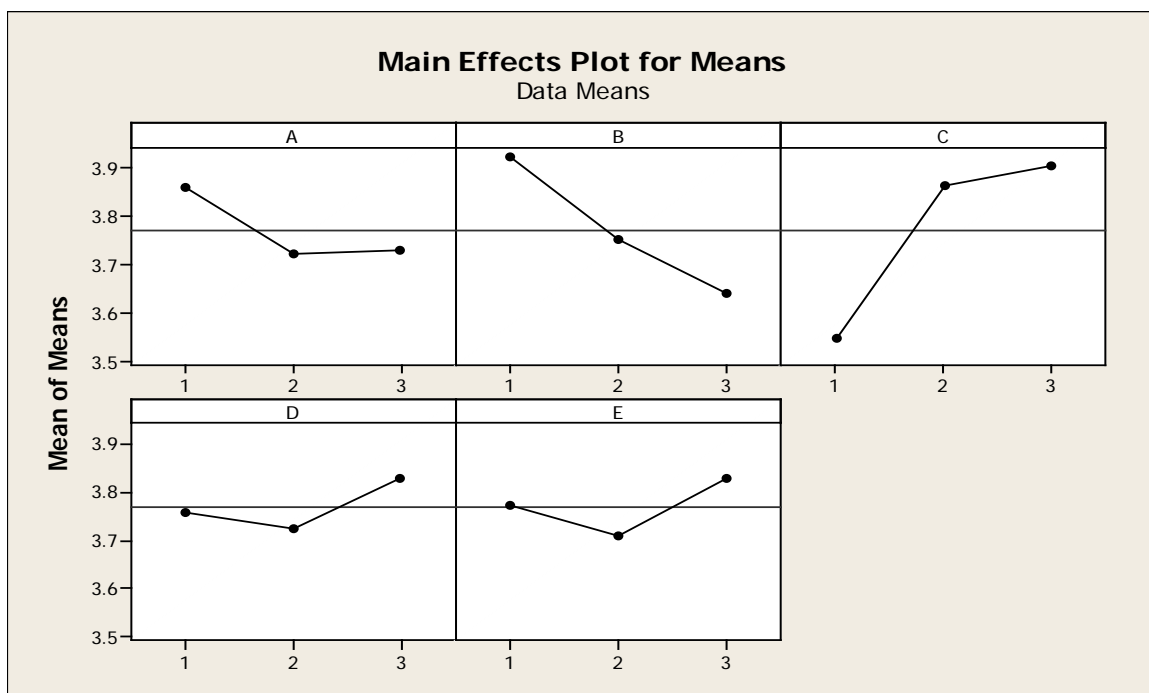


Fig . 5 Main Effects Plot for Means for SR

With the above graph for S/N ratio for SR and Mean for SR we have found the optimal parameter setting A2B3C1D2E2 which is voltage at level 2 (140 Volt), Discharge current at level 3 (32 Amp), Pulse duration at level 1 (6 μ sec), pulse frequency at level 2 (70 KHz), Wire tension at level 2 (1200 gm).

CONCLUSION

Based on Taguchi analysis for Material removal rate, pulse frequency is the most significant factor because it is having 1 rank in case of MRR and predicted optimal parameter setting is A3B3C1D1E3. According to predicted optimal setting we have conducted the experiment and MRR found 0.9827 mm³/min. In the case of surface roughness pulse duration is the most significant factor because it is having 1 rank in case of SR and predicted optimal parameter setting are A2B3C1D2E2. According to predicted optimal parameter setting for SR we have found 2.987 μ m that shows the successful implementation of Taguchi analysis.

REFERENCES

- [1] Y.K. Lok, T.C. Lee, Processing of advanced ceramics using the wire-cut EDM process, J. Mater. Process. Technology. 63 (1–3) (1997) 839–843.
- [2] J.T. Huang, Y.S. Liao, W.J. Hsue, Determination of finish-cutting operation number and machining parameters setting in wire electrical discharge machining, J. Mater. Process. Technol. 87 (1999) 69–81.
- [3] Y.S. Liao, J.T. Huang, H.C. Su, A study on the machining-parameters optimization of wire electrical discharge machining, J. Mater. Process. Technol. 71 (1997) 487–493.
- [4] Ranjit K.Roy, “A Premier On The Taguchi Method” , Van Nostrand Reinhold, New York, 1996.
- [5] Ranjit K.Roy, “Design of Experiments Using the Taguchi Approach” , John Wiley & Sons, New York, 2001.
- [6] B.H. Yan, C.C. Wang, W. D.Liu and F.Y. Huang, “Machining Characteristics of Al₂O₃/6061 Al Composite using Rotary EDM with a Disklike Electrode” , The International Journal of Advanced Manufacturing Technology, 16:322-333, 2000.
- [7] S.S. Mahapatra, and A. Patnaik,, Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, *International Journal of Advanced Manufacturing Technology*, 2007. Vol. 34, pp. 911-92.
- [8] T.A. Spedding, Z.Q. Wang, Parametric optimization and surface characterization of wire electrical discharge machining process, Precision Eng. 20/1 (1997) 5–15.