OPTIMIZATION OF CIRCULARITY ERROR WITH TAGUCHI FOR SAE-4130 CONSIDERING SURFACE RESPONSES IN WIRE-EDM MACHINING

G. Narendranath[1a,b], J. Udaya Prakash[2]

[1] a. Research scholar, Department of Mechanical Engineering, Vel Tech Rangarajan Dr Sagunthala R&D Institute of Science and Technology, Avadi, Chennai - 600062, India

[1]b.Assistant professor, Department of Mechanical Engineering, SEAT, Tirupati-517501, A.P, India.

[2] Department of Mechanical Engineering, Vel Tech Rangarajan Dr Sagunthala R&D Institute of Science and Technology, Avadi, Chennai - 600062, India.

Corresponding author

udayaprakashj@gmail.com

Abstract: Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts of hard materials with complex shapes. Parts having sharp edges that pose difficulties to be machined by the main stream machining processes can be easily machined by WEDM process. Technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted noncontact technique of material removal with a difference that spark is generated at wire and work piece gap. In this paper experiments are carried out to examine the effect of W-EDM parameters such as cutting speed, feed rate, and depth of cut on responses like; roundness, surface roughness, during W-EDM of SAE 4130. Analysis of Variance (ANOVA) is performed and the influence of parameters on each response is studied. The optimal values of parameters obtained from the study are further confirmed by conducting experiments using Taguchi methods.

Keywords: W-EDM, Circularity, ANOVA, Taguchi, Optimization.

1.0 INTRODUCTION

Wire EDM (Electric Discharge Machining) is a thermo- electrical process which material is eroded by a series of sparks between the work piece and the wire electrode (tool). The part and wire are immersed in a dielectric (electrically non-conducting) fluid which also acts as a coolant and flushes away debris The movement of wire is controlled numerically to achieve the desired three-dimensional shape and high accuracy of the work piece Wire EDM, is not the new kid of machining. It was introduced in the late 1960s’, and has revolutionized the tool and die, mold, and metalworking industries. The Spark Theory on a wire EDM is basically the same as that of the vertical EDM process. Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second. The heat of each electrical spark, estimated at around 15,000° to 21,000° Fahrenheit. This process has been widely used in aerospace, nuclear and automotive industries, to machine precise, complex and irregular shapes in various difficult-to-machine electrically conductive materials Recently, WEDM process is also being used to machine a wide variety of miniature and micro-parts in metals, alloys, sintered materials, cemented carbides, ceramics and silicon These characteristics makes WEDM a process which has remained as a competitive and economical machining option fulfilling the demanding machining requirements imposed by the short product development cycles and the growing cost pressures A wire EDM generates spark discharges between a small wire electrode and a work piece with de-ionized water as the dielectric medium and erodes the work piece to produce complex two- and three-dimensional shapes according to a numerically controlled (NC) path. The main goals of WEDM manufacturers and users are to achieve a better stability and higher productivity of the WEDM process. As newer and more exotic materials are developed, and more complex shapes are presented, conventional machining operations will continue to reach their limitations and the increased use of the WEDM in manufacturing will continue to grow at an accelerated rate Wire electrical discharge machining manufacturers and users emphasize on achievement of higher machining productivity with a desired accuracy and surface finish. However, due to a large number of variables even a highly skilled operator with a state-of-the-art WEDM is rarely able to achieve the optimal performance an effective way to solve this problem is to determine the relationship between the performance measures of the process and its controllable input parameters.

1.1 Applications of Wire EDM:

- Machining of accurate profiles for automobile and aerospace components.
- Widely using for dies and moulds where the material strength is high.
- Useful in all metal machining which is having conducting nature.
- Mostly useful for hard material machining.

1.2 Objective of this study:

is to investigate the effects of the drilling parameters on surface roughness and circularity error, and is to determine the optimal drilling parameters using the Taguchi method later the results fed to multiple attributes in decision making techniques (AHP and TOPSIS) are applied to optimal process.

2.0 LITERATURE REVIEW

P. Srinivasa Rao et. al. [1] considered the impact of the most relevant EDM factors over MRR, device wear rate (TWR), Ra and hardness of ss 304 by copper tool electrode. So as to

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

accomplish factorial plan of tests and numerous relapses examination procedures have been utilized to show the already specified reaction factors by methods for conditions as polynomials. On account of MRR, all the plan factors are affecting for a certainty level of 95% and orchestrated in plunging request of significance, servo voltage, obligation cyle, current and voltage keeping in mind the end goal to acquire the high estimation of MRR the work interim of present, servo and obligation cycle (t) ought to be settled as high as could be expected under the possible AsifIqbal et. al. [2] built up experimental relations with respect to machining parameters and the reactions in examining the machinability of the SS 304 utilizing copper anode. The machining factors utilized were voltage, rotational speed of cathode and feed rate over the reactions MRR, EWR and SR. S. Gopalakannan et. al. [3] investigated the impact of beat current on material removal rate, electrode wear, surface roughness and diameter all over cut in erosion safe treated steels viz., ss316 L and 17-4 PH. They watched that the yield parameters, for example, MRR, EWR and Ra of EDM increment with increment in beat current. R. Thani gaivelan et. al.[4] examined the impact and parametric streamlining of process parameters

for electro chemical micro machining (EMM) of SS 304 utilizing dim social investigation, by utilizing machining voltage, beat on-time, electrolyte focus and apparatus tip shapes as common process parameters The trial comes about uncovered that, the conelike with adjusted anode, machining voltage of 9V, pulse on-time of 15ms and electrolyte convergence of 0.35mole/l was the ideal blend for higher machining rate and lesser over cut. S. Ajaya kumar et al [5] to a small-scale application machining elective pulling in a lot of research interests and Electro chemical machining (ECM) offers a few extraordinary favorable circumstances including higher machining rate, better accuracy and control, and a more extensive scope of materials that can be machined Selvakumarv et. al. [6] used Taguchi methodology to study the influence of both machine controllable factors (wire tension, pulse-on time, pulse frequency, peak current and servo voltage) and machine uncontrollable factors (flushing nozzle height, workpiece thickness and corner angle) on material removal rate, surface roughness and corner error for machining Monel 400 alloy. Sanchez et. al. [7] studied the accuracy of corner geometry generated by successive cuts (roughing and finishing) and identified the errors at different zones of the corner which related to the removed material during each cut. The authors also discussed the influence of machining parameters such as work thickness, corner radius and the number of trim cuts and noticed that the errors generated by the previous cuts should be considered in a corner accuracy optimization procedure. Hsue et. al. [8] also built a model which can identify the rate of the removed material in corner cutting by using a fundamental geometry analysis. Hanet al. [9] proposed a control method to improve the corner machining accuracy in rough cutting and implemented a FEM simulation method. The authors also proposed a corner error simulation method to predict the accuracy of the actual corner profile under different cutting conditions. Zhi Chen et. al. [10] performed a study to improve the geometrical accuracy of rough corner cutting with different angles (45◦, 90◦, and 135◦ angle). The authors also applied Taguchi approach to identify the main effect of controllable factors on corner error and proposed an elliptic fitting

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

method to present the trajectory of the wire electrode center. It is concluded that the corner error is decreased more than 50% in rough corner cutting (at 5 mm/min cutting feed rate) by using the optimized control factors combination. Lin et al. [11] improved machining accuracy by designing a closed loop wire tension control system which reduced 50% corner-error and significantly improved the vertical straightness. proposed a control strategy based on fuzzy logic to improve the corner machining accuracy in which more than 50% the accuracy of the corner machining can be improved while the machining time is not higher than 10% of the normal machining process. Danial Ghodsiyeh et al [12] Wire-electro discharge machining (WEDM) has become an important non-traditional machining process, as it provides an effective solution for producing components made of difficult-to-machine materials like titanium, zirconium, etc., and intricate shapes, which are not possible by conventional machining methods. Due to large number of process parameters and responses lots of researchers have attempted to model this process.

3.0 Experimental Method:

The experiments were performed on Robofil 100 high precision five axis CNC WEDM, which is manufactured by Charmilles Technologies Corporation. The basic parts of the WEDM machine consists of a wire, a work table, a servo control system, a power supply and dielectric supply system. The Robofil 100 allows the operator to choose input parameters according to the material and height of the work piece and tool material from a manual provided by the WEDM manufacturer. The Robofil 100 WED machine has several special features. The pulse power supply uses a transistor-controlled RC circuit. The discharge energy is determined by the value of the capacitor that is parallel to the machining gap. The experimental set-up for the data acquisition of the sparking frequency and machine table speed is illustrated in the Fig. 2. The WEDM process generally consists of several stages, a rough-cut phase, a rough cut with finishing stage, and a finishing stage. During the rough-cut phase metal removal rate is of primary importance. Only during the rough cut with finishing stage are metal removal rate and surface finish both of primary importance. This means that the rough cut with finishing phase is the most challenging phase because two goals must simultaneously be considered. We shall therefore consider the rough cut with finishing phase here.

3.1 Materials -SAE 4130

AISI or SAE 4130 grade is a low-alloy steel containing chromium and molybdenum as strengthening agents. The steel has good strength and toughness, weld ability and machinability.

Ultimate Tensile Strength:	670 MPa
Tensile Yield Strength:	435 MPa
Modulus of Elasticity:	205 GPa

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

3.2 OPTIMIZATION METHODS

The degree of freedom for the orthogonal array should be greater than or at least equal to that of the process parameters. There by, a L16 orthogonal array having degree of freedom equal to (16-1) 15has been considered, which is used to optimize the cutting parameters for surface roughness and circularity deviation using the S/N ratio and ANOVA for machining of SAE 4130 predicted results were nearer to the experimental results.

- Non-traditional search and optimization methods are becoming very popular in engineering optimization problems.
- The various non-traditional optimization methods used in this work are as follows
- Taguchi method of optimization using Mini-tab
- ANOVA with linear model of L16 by taking output as surface roughness and circularity.

3.3 Taguchi experiments design

To design of experiment (DOE), the Taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than a fractional factorial design. By Taguchi techniques, industries are able to greatly reduce product development cycle time for design and production, therefore reducing costs and increasing profit Confirmation test have been carried out to compare the predicted values with the experimental values confirm its effectiveness in the analysis of surface roughness and circularity deviation. Design procedure for experiment of various diameters and profiles has been observed to check the cutting speed variation in different profiles and thickness. AutoCAD 2017 used to prepare the drawing for Wire EDM process and the program has been generated with wire cam software. The experimental table given below shows the experimental layout of each drawing and profile.

- The Taguchi method offers a strategy for finding optimal, stable results based on a predefined set of analysed parameter combinations.

It is used to gain more accurate answers on system behaviour and interaction effects, especially when created on basis of fractional factorial designs. Experimental data for 1cut,2cut and 3cut with brass wire of ϕ 0.25mm

The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The machining parameters and their levels are given in Table.

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

Table:1 Variable parameters of experiment

Parameters	Level 1	Level 2	Level 3	Level 4
Thickness variance- work piece	6mm	8mm	10mm	12mm
Number of cuts	R1	F1	F2	F3
Nozzle height from top surface	9mm	29mm	39mm	49mm

Table:2 DOE-L16 Experiments for Taguchi optimization

S.no	**P1 (A)**	**P2(B)**	**P3-C**	**A**	**B**	**C**
1	1	1	1	6	R1	9
2	1	2	2	6	F1	29
3	1	3	3	6	F2	39
4	1	4	4	6	F3	49
5	2	1	2	8	R1	29
6	2	2	3	8	F1	39
7	2	3	4	8	F2	49
8	2	4	1	8	F3	9
9	3	1	3	10	R1	39
10	3	2	4	10	F1	49
11	3	3	1	10	F2	9
12	3	4	2	10	F3	29
13	4	1	4	12	R1	49
14	4	2	1	12	F1	9
15	4	3	2	12	F2	29
16	4	4	3	12	F3	39

Table: 3 Standard Parameters Considered for Experiments of Wire Cut EDM

Parameter Name	**Unit**	1
Tension	**N**	**6**
Feed	m/min	12
Flushing pressure	Kg/cm^2	4
Current	A	100

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

4.0 Experimental work:

Work has been carried out by Taguchi parameters table for the output responses MRR calculated as cutting speed of the machine X wire diameter X work piece thickness in all cuts; relatively circularity error and surface finish observed using CMM and SJ-210durface roughness tester.

Figure: 1 Experimental output after machining for error check

Figure: 2Contour profiles and round profiles

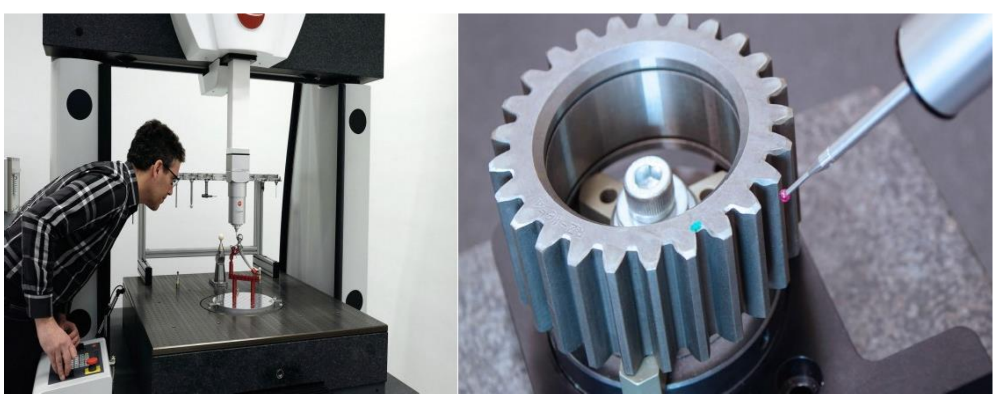


Figure: 3 Circularity Check with CMM

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

5.0 Results and discussions

Table:4 shows circular deviation Radius error of male gear pattern

S. no	(Cutting speed mm/min)					Circularity Error	Surface roughness
	R1	R2	Gear teeth - 1	Gear teeth - 2	R3	mm	(µm)
1	1.82	1.85	1.93	2.01	2.10	0.0120	2.5569
2	6.35	6.37	6.38	6.40	6.42	0.0127	2.5011
3	6.50	6.51	6.53	6.55	6.56	0.0109	2.423
4	6.82	6.85	6.86	6.87	6.89	0.0134	2.8834
5	1.52	5.82	6.83	6.85	6.88	0.0124	3.102
6	6.42	6.45	6.46	6.48	6.50	0.0157	3.256
7	6.64	6.65	6.66	6.68	6.70	0.0177	3.723
8	6.88	6.90	6.92	6.94	6.97	0.0099	3.384
9	1.32	6.94	6.96	6.93	6.95	0.0140	2.832
10	6.40	6.42	6.44	6.45	6.47	0.0154	2.390
11	6.66	6.67	6.68	6.70	6.71	0.0110	2.143
12	6.88	6.89	6.92	6.93	6.95	0.0178	2.236
13	3.45	4.55	5.20	5.22	5.48	0.0185	3.733
14	6.54	6.59	6.62	6.63	6.67	0.0080	3.379
15	6.64	6.65	6.68	6.70	6.73	0.0120	2.824
16	6.72	6.74	6.78	6.80	6.83	0.0139	2.388

Table:5 shows circular deviation Radius error of Female gear pattern

S. no	Cutting speed mm/min					Circularity	Surface roughness
	R1	R2	Gear teeth - 1	Gear teeth - 2	R3	mm	(µm)
1	8.0	8.02	8.04	8.8	8.90	0.0070	2.392
2	8.04	8.6	9.0	9.02	9.08	0.0050	2.384
3	7.90	7.92	7.98	8.02	8.12	0.0096	2.526
4	7.92	7.98	8.05	8.16	8.24	0.0068	2.792
5	8.02	8.09	8.16	8.26	8.28	0.0016	2.631
6	7.98	8.0	8.04	8.09	8.15	0.0062	2.641
7	8.05	8.09	8.13	8.22	8.26	0.0045	2.843

8	7.95	7.98	8.00	8.12	8.18	0.0092	2.891
9	8.08	8.15	8.19	8.25	8.32	0.0106	3.317
10	8.06	8.08	8.10	8.18	8.22	0.0156	3.281
11	7.95	7.97	8.00	8.12	8.18	0.0100	2.476
12	7.94	8.12	8.19	8.24	8.32	0.0097	2.253
13	8.06	8.09	8.12	8.14	8.21	0.0109	3.312
14	8.08	8.11	8.18	8.26	8.27	0.0144	3.275
15	7.89	7.92	8.01	8.04	8.11	0.0101	2.479
16	7.93	8.01	8.13	8.16	8.21	0.0094	2.258

Table:6 shows cutting speed vs MRR for male gear pattern

S. no	(Cutting speed mm/min)					MRR (mm^3/min)				
	R1	R2	Gear teeth - 1	Gear teeth - 2	R3	R1	R2	Gear teeth - 1	Gear teeth - 2	R3
1	1.82	1.85	1.93	2.01	2.10	2.73	2.775	2.895	3.015	3.15
2	6.35	6.37	6.38	6.40	6.42	9.525	9.555	9.57	9.6	9.63
3	6.50	6.51	6.53	6.55	6.56	9.75	9.765	9.795	9.825	9.84
4	6.82	6.85	6.86	6.87	6.89	10.23	10.275	10.29	10.305	10.335
5	1.60	1.62	1.63	1.65	1.72	3.2	3.24	3.26	3.30	3.42
6	6.42	6.45	6.46	6.48	6.50	12.84	12.9	12.92	12.96	13
7	6.64	6.65	6.66	6.68	6.70	13.28	13.3	13.32	13.36	13.4
8	6.88	6.90	6.92	6.94	6.97	13.76	13.8	13.84	13.88	13.94
9	1.42	1.44	1.46	1.33	1.45	3.575	3.60	3.65	3.325	3.625
10	6.40	6.42	6.44	6.45	6.47	16	16.05	16.1	16.125	16.175
11	6.66	6.67	6.68	6.70	6.71	16.65	16.675	16.7	16.75	16.775
12	6.88	6.89	6.92	6.93	6.95	17.2	17.225	17.3	17.325	17.375
13	1.25	1.35	1.20	1.22	1.48	3.75	4.05	3.60	3.66	4.44
14	6.54	6.59	6.62	6.63	6.67	19.62	19.77	19.86	19.89	20.01
15	6.64	6.65	6.68	6.70	6.73	19.92	19.95	20.04	20.1	20.19
16	6.72	6.74	6.78	6.80	6.83	20.16	20.22	20.34	20.4	20.49

Table:7 shows cutting speed vs MRR for Female gear pattern

S. no	(Cutting speed mm/min)					MRR (mm^3/min)				
	R1	R2	Gear teeth - 1	Gear teeth - 2	R3	R1	R2	Gear teeth - 1	Gear teeth - 2	R3
1	1.33	1.36	1.28	1.32	1.40	1.729	2.04	1.92	1.716	2.1
2	8.04	8.6	9.0	9.02	9.08	12.06	12.9	13.5	13.53	13.62
3	7.90	7.92	7.98	8.02	8.12	11.85	11.88	11.97	12.03	12.18
4	7.92	7.98	8.05	8.16	8.24	11.88	11.97	12.075	12.24	12.36
5	1.02	1.09	1.16	1.26	1.28	2.04	2.18	2.32	2.52	2.56
6	7.98	8.0	8.04	8.09	8.15	15.96	16	16.08	16.18	16.3
7	8.05	8.09	8.13	8.22	8.26	16.1	16.18	16.26	16.44	16.52
8	7.95	7.98	8.00	8.12	8.18	15.9	15.96	16	16.24	16.36
9	1.08	1.15	1.19	1.25	1.32	2.70	2.875	2.737	3.125	3.30
10	8.06	8.08	8.10	8.18	8.22	20.15	20.2	20.25	20.45	20.55
11	7.95	7.97	8.00	8.12	8.18	19.875	19.925	20	20.3	20.45
12	7.94	8.12	8.19	8.24	8.32	19.85	20.3	20.475	20.6	20.8
13	1.06	1.09	1.12	1.14	1.21	3.18	3.27	3.36	3.42	3.63
14	8.08	8.11	8.18	8.26	8.27	24.24	24.33	24.54	24.78	24.81
15	7.89	7.92	8.01	8.04	8.11	23.67	23.76	24.03	24.12	24.33
16	7.93	8.01	8.13	8.16	8.21	23.79	24.03	24.39	24.48	24.63

Table: 8,9Taguchi Analysis: CE, SR versus A, B, C

Estimated Model Coefficients for SN ratios &Means

Term	Coef	SE Coef	T	P
Constant	-5.6494	0.1002	-56.363	0.000
A 1	0.6376	0.1736	3.672	0.010
A 2	-0.1239	0.1736	-0.714	0.502
A 3	-0.2567	0.1736	-1.479	0.190
B 1	-0.5390	0.1736	-3.104	0.021

Term	Coef	SE Coef	T	P
Constant	1.37161	0.01437	95.470	0.000
A 1	-0.10631	0.02488	-4.272	0.005
A 2	0.00682	0.02488	0.274	0.793
A 3	0.05000	0.02488	2.009	0.091
B 1	0.08865	0.02488	3.562	0.012
B 2	0.08116	0.02488	3.262	0.017
B 3	-0.07684	0.02488	-3.088	0.021
C 1	-0.14666	0.02488	-5.894	0.001
C 2	-0.14994	0.02488	-6.025	0.001
C 3	0.13499	0.02488	5.425	0.002

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

B 2	-0.4918	0.1736	-2.833	0.030
B 3	0.4384	0.1736	2.525	0.045
C 1	0.9196	0.1736	5.297	0.002
C 2	0.9373	0.1736	5.399	0.002
C 3	-0.8376	0.1736	-4.825	0.003

Model Summary

S	R-Sq	R-Sq(adj)
0.4009	95.48%	88.70%

Table: 10 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	2.2150	2.2150	0.7383	4.59	0.054
B	3	4.3020	4.3020	1.4340	8.92	0.012
C	3	13.8590	13.8590	4.6197	28.74	0.001
Residual Error	6	0.9644	0.9644	0.1607		
Total	15	21.3404				

Linear Model Analysis: Means versus A, B, C

Model Summary

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

S	R-Sq	R-Sq(adj)
0.0575	96.43%	91.06%

Table: 11 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	0.06519	0.06519	0.021731	6.58	0.025
B	3	0.11598	0.11598	0.038659	11.71	0.006
C	3	0.35333	0.35333	0.117775	35.66	0.000
Residual Error	6	0.01982	0.01982	0.003303		
Total	15	0.55431				

Table: 12 Linear Model Analysis:Estimated Model Coefficients for StDevs

Term	Coef	SE Coef	T	P
Constant	1.92733	0.02033	94.801	0.000
A 1	-0.14796	0.03521	-4.202	0.006
A 2	0.01448	0.03521	0.411	0.695
A 3	0.06691	0.03521	1.900	0.106
B 1	0.12716	0.03521	3.611	0.011
B 2	0.11264	0.03521	3.199	0.019
B 3	-0.10833	0.03521	-3.076	0.022
C 1	-0.20651	0.03521	-5.865	0.001
C 2	-0.20895	0.03521	-5.934	0.001
C 3	0.18784	0.03521	5.334	0.002

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

Model Summary

S	R-Sq	R-Sq(adj)
0.0813	96.36%	90.89%

Table: 13 Analysis of Variance for StDevs

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	0.12405	0.12405	0.041349	6.25	0.028
B	3	0.23150	0.23150	0.077168	11.67	0.006
C	3	0.69361	0.69361	0.231202	34.96	0.000
Residual Error	6	0.03968	0.03968	0.006613		
Total	15	1.08883				

Response Table 14: Signal to Noise Ratios, Means& Std (Smaller is better)

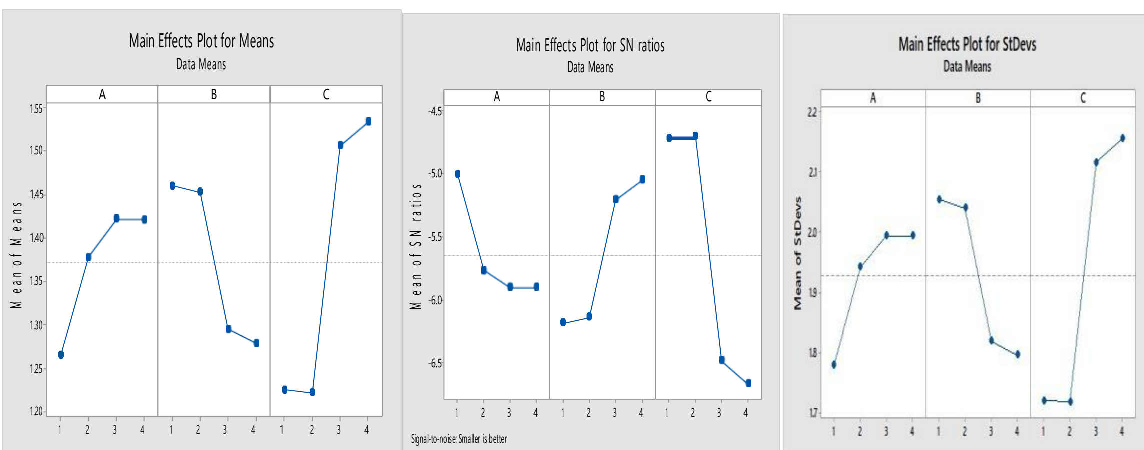
Level	A	B	C
1	-5.012	-6.188	-4.730
2	-5.773	-6.141	-4.712
3	-5.906	-5.211	-6.487
4	-5.906	-5.057	-6.669

Level	A	B	C
1	1.265	1.460	1.225
2	1.378	1.453	1.222
3	1.422	1.295	1.507
4	1.421	1.279	1.533
Delta	0.156	0.182	0.312
Rank	3	2	1

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

Delta	0.894	1.131	1.957
Rank	3	2	1

Level	A	B	C
1	1.779	2.054	1.721
2	1.942	2.040	1.718
3	1.994	1.819	2.115
4	1.994	1.796	2.155
Delta	0.215	0.259	0.437
Rank	3	2	1



Conclusions

Present work focuses on the different parameters which can decrease the radius errors with surface finish of the component, mean radius check at different parameters with CMM to finalize the error data, optimization had been done with Taguchi experimental design. Observing the overall predicted results1 cut with 29mm nozzle distance given better results compared with others.

Vol. 21, No. 1, (2024)
ISSN: 1005-0930

REFERENCES:

1. P. Srinivasa Rao, J. Suresh Kumar, (2010) Parametric Study of Electrical discharge Machining of Aisi 304stainless Steel" International Journal of Engineering Science and Technology vol. 2(8), Pp. 3535-3550.
2. AsifIqbal, A. K. M., Khan, Ahsan Ali (2014) "Modeling and Analysis of MRR, EWR and Surface Roughness in EDM Milling through Response Surface Methodology" American Journal of Engineering and Applied Sciences 3(4), pp. 611-619.
3. Subramanian Gopalakannan, Thiagarajan Senthilvelan (2012) "Effect of Electrode Materials on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels" Journal of Minerals and Materials Characterization and Engineering, pp.685-690,
4. R. Thanigaivelan and Ramanathan Arunachalam (2013) Optimization of process parameters on machining rate and overcut in electrochemical micromachining using grey relational analysis" Journal of Scientific & Industrial Research, Vol. 72, January 2013, pp. 36-42.
5. S. Ajaya Kumar1, A. Prabhu Kumar2 & B. Balunaik3 optimization of cutting speed parameter for roundness study in wire EDM for different materials by Taguchi method International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 8, Issue 4, Aug 2018, 647-652
6. Selvakumar, G, Thiruppathi, K. K, Selvaraj, M, Manohar, J. "Enhancing die corner accuracy using path modification strategy in wire electrical discharge machining of Monel 400", Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science 232 – 2, pp. 207 – 216, 2018.
7. Sanchez, J.A., Plaza, S., Ortega, N., Marcos, M., Albizuri, J. "Experimental and numerical study of angular error in wire-EDM taper-cutting", International Journal of Machine Tools and Manufacture 48 (12 – 13), pp. 1420 – 1428, 2008.
8. Hsue W. J., Liao, Y. S., Lu, S. S. "Fundamental geometry analysis of wire electrical discharge machining in corner cutting", International Journal of Machine Tools and Manufacture 39 (4), pp. 651 – 667, 1999.
9. Han, F., Zhang, J., Soichiro, I. "Corner error simulation of rough cutting in wire EDM", Precision Engineering 31 (4), pp. 331 – 336, 2007.
10. Zhi Chen, Hongbing Zhou, Zhaojun Yan, Fenglin Han, Hongzhi Yan "A new high speed observation system for evaluating the spark location in WEDM of Inconel 718", Journal of Materials Research and Technology 13, pp. 184 – 196, 2021.
11. Chin-Teng Lin, I-Fang Chung, Shih-Yu Huang "Improvement of machining accuracy by fuzzy logic at corner parts for wire-EDM", Fuzzy Sets and Systems 122 (3), 499 -511, 2001.
12. Danial Ghodsiyeh, Abolfazl Golshan, Jamal Azimi Shirvanehdeh Review on Current Research Trends in Wire Electrical Discharge Machining (WEDM) Indian Journal of Science and Technology Vol: 6 Issue: 2 February 2013 ISSN:0974-6846