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Analysis and Optimization of Surface Roughness and Kerf Width in WEDM for SS304 Using Taguchi Design of Experiment

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Abstract **Wire electric discharge machining (WEDM) is new concept introduce in middle of nineteen century. It is use for hard and robust conducting smart material which is use in Aerospace industries, Medical industries Tool and Die industries etc. The experiment is performed with input parameters like cutting voltage, pulse on time, pulse off time, servo voltage, wire tension, wire feed, dielectric pressure by varying thickness of work piece. Taguchi L9 orthogonal array is use for design experiment. ANOVA and Signal to Noise ratio (S/N) statical model is use to find optimal value of kerfs width and surface roughness of stainless steel 304. It has been found that pulse on time is most significant parameter. Here we choose input parameter is pulse on time, pulse off time and feed.**

Key words: WEDM, KERF WIDTH, SURFACE ROUGHNESS, TAGUCHI MODEL, ANOVA MINITAB.

I. INTRODUCTION

Conventional manufacturing process is use for machining ductile and soft material with little specification. It is difficult to machining hard material with many details. To overcome such difficulty non conventional machining process is developed. In this process there is indirect contact between tool and work piece. This is use for only conducting material this is an expensive process which require high capital investment for installation.non conventional machining process is classified on the nature of force required for remove material. Below fig.1.1 show Classification of non- traditional machining process..

NUMECLATURE:

WEDM	Wire Eletctric Discharge machining
T on	Pulse on time
T off	Pulse off time
SS 304	Stainless Steel 304
ANOVA	Analysis of variance
KW	Kerf width
SR	Surface Roughness
DF	Degrees of freedom
SS	Sum of squares
MS	Mean square(Variance)
S/N Ratio	Signal to Noise Ratio

II. DESIGN OF EXPERIMENT

In Engineering Design work, Design of experiment (DOE) is effective tool to investigate the process parameter that influence the output. In other words it is use to find cause and effect relationship. This information is needed to manage process inputs in order to optimize output. Here we use three methods for design of experiment which are:-

- Taguchi method.
- Factorial method.
- Response surface method.

In this thesis we use Taguchi method.

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum setting "of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

Process parameters selection: In this thesis we select seven input parameter and two output parameters. We are taking Wire feed(m/min), Pulse on time (TON), Pulse off time (TOFF), Cutting voltage, Servo voltage, Dielectric

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pressure and Wire tension. For analysis of surface roughness and kerf width.

INPUT PARAMETERS WITH LEVELS VALUE:

Table: 3.1

S.N	Parameter	Level 1	Level 2	Level 3
1	WFR (m/min.)	6	8	10
2	TON (μs)	110	115	120
3	TOFF (μs)	50	55	60

Fixed factors:

Table 3.2 Input parameter with fixed value:

S.N	Fixed parameter	Set value
1	Wire material & its diameter	Brass wire (0.25mm)
2	Work piece & its thickness	SS304 (10mm)
3	Flushing pressure	1.2 kgf/cm^2
4	Die electric fluid	Deionize water

Experimental design:

As per table, L9 orthogonal array of Taguchi method has been selected for the experiments design in software MINITAB 17.

L9 ()

Factors: 4

N Taguchi= 1+ NV (L-1)

Where

N Taguchi= Number of experiment to be run.

NV= Number of parameters

L= Number of levels

III. ANALYSIS OF SURFACE ROUGHNESS

Analysis of process parameter which affect surface roughness is obtained by using MINITAB 17.We select L9 model for calculation of S/N Ratio, and use smaller is better concept because minimum surface roughness is my aim.

Table 5.2 Experimental value of surface roughness and its S/N Ratio.

Surface roughness	S/N Ratio
2.556	-8.15122
2.501	-7.96227
2.423	-7.68707
1.834	-5.26799
1.564	-3.88473
2.345	-7.40286
1.345	-2.57445
1.453	-3.24531
1.453	-3.24531

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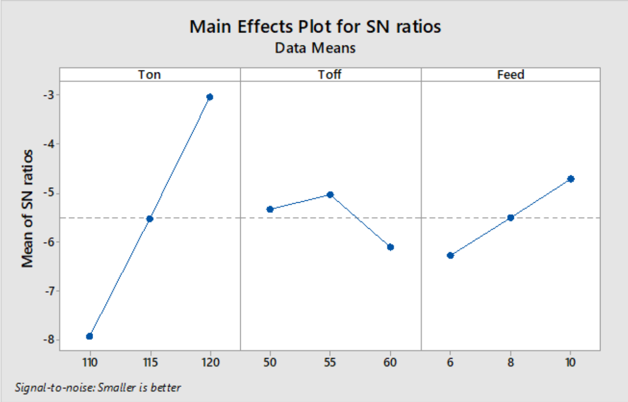

Fig 5.1 Effect of process parameter on surface roughness S/N Ratio graph.

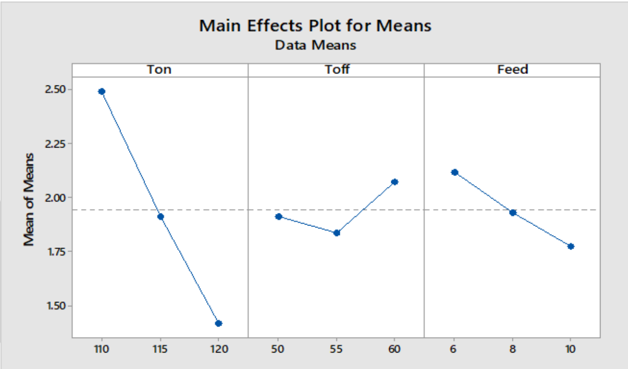

Fig 5.2 the Effect of process parameter in surface roughness mean of mean graph.

Table 5.3 Response table for signal to noise ratio for smaller is better for surface roughness.

Level	Ton	T off	Feed
1	-7.934	-5.331	-6.266
2	-5.519	-5.031	-5.492
3	-3.022	-6.112	-4.715
Delta	4.912	1.081	1.551
Rank	1	3	2

Table 5.4 Response table for means

Level	Ton	T off	Feed
1	2.493	1.912	2.118
2	1.914	1.839	1.929
3	1.417	2.074	1.777
Delta	1.076	0.234	0.341
Rank	1	3	2

From the above table optimal level combination factor for surface roughness is 110μs(level 1) for Ton,60μs (level 3) for T off, 6m/min (level 1) for wire feed.

ANOVA FOR SURFACE ROUGHNESS (SR):

Source	DF	Seq.SS	Contribution	Adj. SS	Adj. MS	F value	P value
Ton	2	2.77799	85.55%	2.77799	1.38900	85.27	0.012
T off	2	0.13224	4.07%	0.13224	0.06612	4.06	0.19

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Feed	2	0.30456	9.38%	0.30456	0.15228	9.35	0.097
Error	2	0.03258	1.00%	0.03258	0.01629		
Total	8	3.24738	100.00 %				

Signal to noise ratio for kerfs width:

Table 5.5 Experimental values of kerfs width and its S/N Ratio.

KW	S/N Ratio
0.65	3.74173
0.68	3.34982
0.69	3.22302
0.75	2.49877
0.77	2.27019
0.79	2.04746
0.73	2.73354
0.77	2.27019
0.75	2.49877

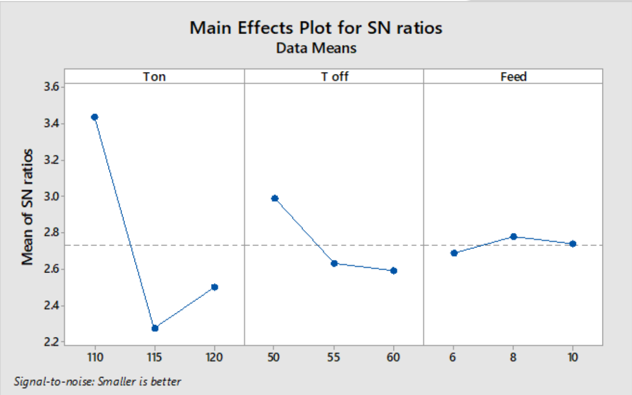

Fig 5.3 Effects of process parameter on kerfs width S/N Ratio graph.

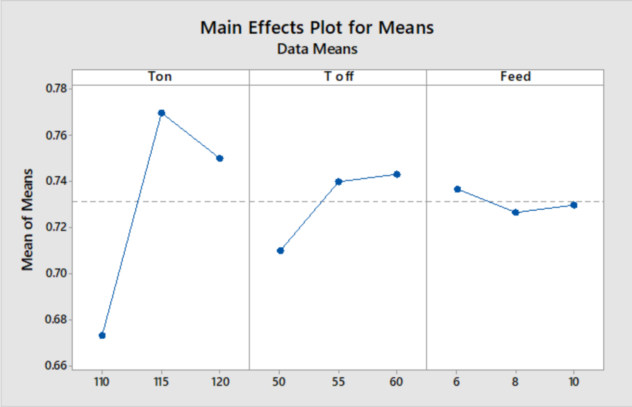

Fig 5.4 Effects of process parameter on means graph for kerfs width.

Table 5.5 Response table for S/N Ratio smaller is better for kerfs width.

Level	Ton	T off	Feed
1	3.438	2.991	2.686
2	2.272	2.630	2.782
3	2.501	2.590	2.742
Delta	1.166	0.402	0.096
Rank	1	2	3

Table 5.6 Response table for means:

Level	Ton	T off	Feed
1	0.6733	0.7100	0.7367
2	0.7700	0.7400	0.7267
3	0.7500	0.7433	0.7300
Delta	0.0967	0.0333	0.0100
Rank	1	2	3

From the above table optimum level combination factors for kerfs width are 110µs (level 1) for Ton, 50µs (level 1) for T off, 8 m/min (level 2) for feed.

Table 5.8 ANOVA for kerfs width (KW):

Source	DF	Seq.SS	Contribution	Adj. SS	Adj. MS	F value	P value
Ton	2	0.01379	80.22%	0.013795	0.006898	110.14	0.009
T off	2	0.00217	12.67%	0.002179	0.001090	17.40	0.054
Feed	2	0.00109	6.38%	0.001098	0.000549	8.76	0.102
Error	2	0.00013	0.73%	0.000125	0.000063		
Total	8	0.01719	100.00%				

IV. RESULT AND DISCUSSION

Discussion for surface roughness based on S/N Ratio:

Analysis of surface roughness is done by TAGUCHI Method in which I select L9 Orthogonal array for analysis of surface roughness by signal to noise ratio and ANOVA method. All the necessary graph for S/N Ratio is shown in Fig.5.1 and Fig 5.2 and table are shown in Table 5.3 and 5.4. From the graph 5.1 it is clear that surface roughness is better at (Ton 120µs at Level 3),(T off 55µs at Level 2),(Feed 10m/minute at Level 3) graph is drawn at smaller is better concept because our aim is minimum surface roughness. From the S/N Ratio Table 5.3 it is clear that (RANK 1) is given to Ton which is dominating parameter, (RANK 2) is given to Feed, (RANK 3) is given to Feed. Ranks are provided according to the contribution of the parameter in the final result. Analysis is done by MINITAB 17.

Discussion for surface roughness based on ANOVA:

ANOVA is a statical method of analysis in which two important parameter P value and F value which inform the researcher which parameter contribution is maximum in the required result. Generally this model is used at 95% confidence level. The P value for at least one parameter

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must be less than 0.05 then the experiment is successful the parameter whose value is less than 0.05 is deciding parameter. From the table 5.7 P value for Ton is 0.012 and its contribution in the result is 85.55%. P value for 'T off' is 0.198 and its contribution is 4.07 % in the result. P value for Feed is 0.097 and its contribution is 9.38% in the final result. Analysis is done by MINITAB 17.

Discussion for Kerfs width based on S/N Ratio:

Analysis of kerfs width is also done by TAGUCHI Method in which we use S/N Ratio for analysis of kerfs width based on smaller is better model because smaller kerfs minimize wastage of material due to vaporization in EDM machining process. From the graph 5.3 it is clear that Kerfs is minimum at (Ton 110µs at Level 1),(T off 50µs at Level 1), (Feed 8m/min. at level 2). In the S/N Ratio table 5.5 Rank is given to different input parameter based on their contribution in the minimization of kerfs, Rank 1 is given to Ton, Rank 2 is given to T off and Rank 3 is given to the Feed. Analysis is done my MINITAB 17.

Discussion for Kerfs width based on ANOVA:

ANOVA is a statical method of analysis in which two important parameter P value and F value which inform the researcher which parameter contribution is maximum in the required result. Generally this model is used at 95% confidence level. The P value for at least one parameter must be less than 0.05 then the experiment is successful the parameter whose value is less than 0.05 is deciding parameter. In the table 5.8 P value is given for every input parameter and their percentage contribution in the final result. P value for Ton is 0.009 and their contribution is 80.225%, P value for "T off" is 0.054 and their contribution is 12.67%, P value for feed is 0.102 and their contribution is 6.385% in the final result. Analysis is done by MINITAB 17.

V.CONCLUSION AND FUTURE SCOPE

Conclusions:

After the analysis of all the experimental data and graph we reached at following conclusion.

There are several parameters in the wire cut EDM process which is selected as input parameter but we are selecting three parameters (Ton, T off, Feed) as input parameters. As pulse on time (Ton) increases surface roughness decrease and we get smoother surfaces and best result we get at 120µs (Ton).

Pulse off time (T off) is increases from 50µs to 60 µs surface roughness is increases continuously and we get better result at 50µs. It affect surface roughness minimum.

With increase in Feed surface roughness decrease as feed increases wire get lesser time to pass through same line hence surface roughness improved.

Kerfs width is the gap generated between work piece and scrap during the movement of wire electrode around the contour, theoretically it is equal to the wire diameter but in actual it is larger than wire diameter. It is dominated by the pulse on time and Feed as pulse on time and feed increases kerfs width decreases. It has little affect of pulse off time.

Future scope:

The mathematical model we use for analysis has three input parameter L9 Array. Researcher may select L27,L18,L36 model with required number of minimum input parameter and get more precise and accurate result. We use (SS304) plate of 10mm thickness for analysis, there are variety of input material like INCONEL,HASTEALLOY other advance material may be selected of different shape sheet, plate, cylindrical rod and other shapes materials may be selected for analysis.

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