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MULTI-RESPONSE OPTIMIZATION OF WIRE-EDM PROCESS VARIABLES FOR MACHINING PROCESS OF ASIS 310

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ABSTRACT –

The wire electrical discharge machining (WEDM) is one the advanced machining process in which thermo electrical energy is utilized for effective machining. The heat generated due sparking results in melting of work piece. so this process is also known as spark erosion. The non-traditional machining techniques are being implemented successfully for machining intricate shapes in advanced materials such as composites. The aim of this project work is to optimize the WEDM process parameters of ASIS 310 material using Taguchi method for designing orthogonal array and grey relational analysis for optimization of parameters. by using Design of Experiments (DOE) concepts L27 orthogonal array is constructed by considering significant input parameters such as pulse on time(T_{on}), pulse off time(T_{Off}),wire tension(WT),wire feed(WF) and servo voltage(SV).the multi responses which we are concentrated are material removal rate(MRR), Kerf Width and surface roughness. The surface testing was performed on tally surf equipment for experimental values of Surface roughness (SR).

1. Introduction:

Wire EDM is an unconventional machining process basically relies on principle of thermo-electrical energy and used for machining intricate shapes in electrically conductive materials [1]. This machining process is also known as spark erosion in which sparking results in melting of work piece by series of discrete passes material will get melted[6] .In this process there will be no mechanical contact between the tool and the work piece so the removal of material is mainly based on the heat energy[7]. In the wire EDM process a very thin wire of diameter about 0.05mm to 0.3mm is used as an electrode to machine the work piece in the required shape. The machining process is controlled by the electrical sparks by the dielectric medium.

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During the machining process sparks will generated that leads to erosion of the material and the tool. And the machining process is used for hard materials which done the machining in conventional machining process. [8] Wire EDM is the complex machining process which depends on the process parameters and the variables. The economics of the machining is mainly based on the proper selection of parameters.

1. EXPERIMENTAL SETUP

Fig-1: Joe marswtt-655 Taiwan make wire cut machine

2.1 Machine Specifications:

Wire material**:** brass

Wire diameter:0.15mm,0.20mm,0.25mm

Material removal in skim pass:0.005mm

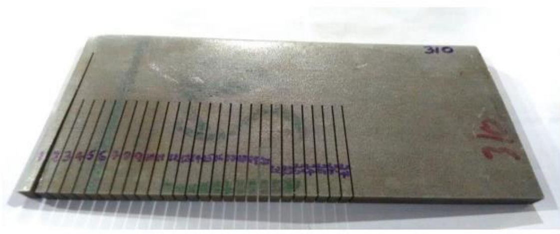
Positional accuracy:0.005mm

Tolerance:0.005mm workpiece thickness:upto 350mm

2.2 Work Piece:

Workpiece:

310 stainless steel



Composition of Stainless Steel 310:

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2.3 Tally Surf Equipment: with the help of the below equipment the value of surface roughness (Ra) is measured

Fig-3 Tally Surf Equipment

3. Input parameters:

3.1 Pulse On-Time:

During the pulse on time the machining process undergoes. It is the time at which the electric current passes through the electrodes and the removes the metallic particles for the work piece. The material removal rate increases with increase in the pulse on time.

3.2 Pulse Off-time:

During the pulse off time their will not undergo any machining process because during this time period the material is removed by using the dielectric fluid. And it may lead to slow down the machining process.

3.3 Wire Feed:

Wire feed indicates the speed at which the wire is supplied to cutting zone. During cutting, both the work pieces and the tool get eroded Wire once used is usually discarded to maintain higher accuracy. In this process, heat energy is delivered through wire in the spark gap and the feed control has to maintain the movement of wire in such a way that the heating temperature to melt work piece material is consistent and uniform. Improper setting of feed rate causes instability leading to detrimental short circuits between work piece and electrode.

3.4 Wire Tension:

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During the machining process their will, be tension in the wire due to electric current passes through the wire. Due to this there will be certain position to hold the wire against the work piece. During the machining process please ensure that wire should be tight to avoid uneven surface finish.

3.5 Servo Voltage:

Servo voltage is varying between the material and the work piece. During machining process, the material removal rate increases with increase in the servo voltage. If the servo voltage increases the machining time also increases and it form debris over the surface during machining

Table 3.5: Design of process parameters:

Symbol	Parameters	Level 1	Level 2	Level 3	Units
A	Pulse on Time	5	9	13	µs
B	Pulse off Time	20	25	30	µs
C	Wire feed rate	1	4	7	m/min
D	Wire Tension	7	8	9	gmf
E	Servo Voltage	30	35	40	V

Metal	**C**	**Mn**	**Si**	**P**	**S**
Comp	**0.25 Max**	**2.00 Max**	**1.50**	**0.045 Max**	**0.030 max**

4. Design of experiments:

4.1. Taguchi method:

It is also known as robust design methods, proposed by G. Taguchi. The conventional method of Taguchi cannot solve problems of multi response optimization. The Taguchi method with combined grey relational analysis is being implemented for the scope of its wide range of applications [2].

4.2. Selection of orthogonal arrays

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It depends upon the prominent selection of input parameters and their respective levels. The selection of number of experiments to be conducted is based on the number of degrees of freedom which can be obtained by the formulae

M+N (L-1)+(N_a-1)(N_b-1)

Where as

M=overall mean,

N=no. of factors,

L= no. of levels

4.3. Notation of the matrix experiments: The notation of the matrix is given by

No. of experiments

$L_{27}(3^5)$

No. of levels

No. of factors

4.4. Calculation of L_{27} Orthogonal array: to consider the no. of experiments to be done.

Overall mean=1

3level factors=5*(3-1) =10

2-factor interactions=16

Total=27

So,L_{27}orthogonal array is selected

5. Optimization Technique

5.1. Grey relational analysis:

In grey relational analysis experiment data are first normalized in the range of 0 to 1. This process is known as grey relational generation. Grey relational coefficients are calculated to represent the co-relation between ideal and actual normalized data. However Taguchi method is used to solve single response Optimization and can't be applied for the multi responses. So, grey relational analysis plays a significant role while approaching multi response Optimization [3]

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2. Methodology of Grey relational analysis (GRA):

A. Grey relational generation:

According to the normalization three types of data normalization are done

1. Smaller the better
2. Larger the better

Smaller the better:

Surface roughness is the major response in WEDM process which is considered as the metal cutting for material.

"Smaller the better" is considered for the surface roughness in which the sequence to standard as follows:

$$y_i(z) = \frac{MAXx_i(z) - x_i(z)}{MAXx_i(z) - MINx_i(z)}$$

Where, y_i (z) and x_i (z) are the sequence after the data preprocessing and comparability sequence respectively, k=1 for Surface roughness,

i =1, 2, 3,4…, 27 for experiment.

Larger the better:

MRR is the major response in WEDM which is considered as the metal removal for the work piece. "Larger the better" is considered for the MRR in which the sequence to standard as follows:

$$y_i(z) = \frac{x_i(z) - MINx_i(z)}{MAXx_i(z) - MINx_i(z)}$$

Where, y_i (z) and x_i(z) are the sequence after the data preprocessing and comparability sequence respectively, k=1 for MRR; i =1, 2, 3,4…, 27 for experiment [4].

B. Grey relational coefficient:

A grey relational coefficient is calculated to express the relationship between the ideal and actual normalized experimental results. The Grey relational coefficient can be express as follows.

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$$\partial_i(z) = \frac{\Delta_{min} + \in \Delta_{max}}{\Delta_{0i}(z) + \in \Delta_{max}}$$

Here $\varepsilon \rightarrow identification\ coefficent$

If all parameters are given equal preference then ε is taken as 0.5

Δ (k) =$|y_0 (z) - y_i (z)|$

Where, Δ(k) is the deviation sequence of reference sequence y_i(k) and the comparability sequence.

$\Delta min = min\ |y_0(z) - y_i (z)|$

$\Delta max = max\ |y_0 (z) - y_i(z)|$ (5)

C. Grey relational grade:

After determining the grey relational coefficient. The mean is be generated to get the grey relational grade. And it can be define as follows:

$$\gamma_{i=\frac{1}{n}} \sum_{z=1}^{n} \partial_i(z)$$

In grey relational analysis, the grey relational grade is used to indicate optimal parameter setting of the input values which are mentioned.

6. Steps to be followed for Optimization:

The fundamental steps to be followed for the Optimization of multi responses are given below:

(a) Experimental designing and execution

(b) Calculation of signal to noise ratio

The Taguchi method aims to define optimal combination of the parameters

(c) Grey relational generation.

The experimental data is in between interval of zero to one[5]

(d) Generation of grey relational grade

The highest grade will have the optimal setting of input parameters.

(e) Effective selection of optimal level parameters

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7. Calculation of Material Removal Rate, Kerf Width and over cut:

Formulas for MRR and Overcut

1. MRR=(volume * density)/time
2. volume= Kerf *length*h
3. over cut=over cut =Kerf - wire diameter

Table 2: Calculation of Material Removal Rate, Kerf Width and Surface Roughness

S.NO	Pulse on Time	Pulse off Time	Wire feed rate	Wire Tension	Servo Voltage	Kerf Width	Material Removal Rate (g/mm3)	Surface roughness (µm)
1	1	1	1	1	1	0.3433	0.0310	0.42
2	1	2	1	2	2	0.3127	0.0236	0.59
3	1	3	1	3	3	0.3170	0.0159	0.455
4	1	1	2	2	2	0.3107	0.0207	0.365
5	1	2	2	3	3	0.3147	0.0289	0.36
6	1	3	2	1	1	0.3117	0.0290	0.46
7	1	1	3	3	3	0.3050	0.0318	0.46
8	1	2	3	1	1	0.3120	0.0369	0.475
9	1	3	3	2	2	0.3153	0.0311	0.5
10	2	1	1	2	3	0.3153	0.0565	0.56
11	2	2	1	3	1	0.3127	0.0515	0.54
12	2	3	1	1	2	0.3087	0.0575	0.58
13	2	1	2	3	1	0.3203	0.0534	0.475
14	2	2	2	1	2	0.3230	0.0577	0.565
15	2	3	2	2	3	0.3197	0.0609	0.395
16	2	1	3	1	2	0.3137	0.0655	0.735
17	2	2	3	2	3	0.3093	0.0697	0.455
18	2	3	3	3	1	0.3263	0.0649	0.615
19	3	1	1	3	2	0.3220	0.0707	0.56

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20	3	2	1	1	3	0.3263	0.0796	0.585
21	3	3	1	2	1	0.3303	0.0725	0.655
22	3	1	2	1	3	0.3257	0.0787	0.715
23	3	2	2	2	1	0.3213	0.0730	0.48
24	3	3	2	3	2	0.3227	0.0752	0.515
25	3	1	3	2	1	0.3183	0.0762	0.715
26	3	2	3	3	2	0.3200	0.0803	0.42
27	3	3	3	1	3	0.3207	0.0988	0.39

Table 3: Normalizing of experimental

S.No	D1(MRR)	D2(SR)
1	0.8182	0.1600
2	0.9067	0.6133
3	1.0000	0.2533
4	0.9419	0.0133
5	0.8432	0.0000
6	0.8420	0.2667
7	0.8077	0.2667
8	0.7462	0.3067
9	0.8167	0.3733
10	0.5095	0.5333
11	0.5702	0.4800
12	0.4977	0.5867
13	0.5475	0.3067
14	0.4956	0.5467
15	0.4575	0.0933
16	0.4014	1.0000
17	0.3505	0.2533
18	0.4086	0.6800

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19	0.3390	0.5333
20	0.2311	0.6000
21	0.3170	0.7867
22	0.2428	0.9467
23	0.3109	0.3200
24	0.2840	0.4133
25	0.2720	0.9467
26	0.2231	0.1600
27	0.0000	0.0800

Table4: Calculation of Deviation Result for all Performance characteristics sequence For MRR and SR:

S.No	MRR	SR
1	0.1818	0.8400
2	0.0933	0.3867
3	0.0000	0.7467
4	0.0581	0.9867
5	0.1568	1.0000
6	0.1580	0.7333
7	0.1923	0.7333
8	0.2538	0.6933
9	0.1833	0.6267
10	0.4905	0.4667
11	0.4298	0.5200
12	0.5023	0.4133
13	0.4525	0.6933
14	0.5044	0.4533

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15	0.5425	0.9067
16	0.5986	0.0000
17	0.6495	0.7467
18	0.5914	0.3200
19	0.6610	0.4667
20	0.7689	0.4000
21	0.6830	0.2133
22	0.7572	0.0533
23	0.6891	0.6800
24	0.7160	0.5867
25	0.7280	0.0533
26	0.7769	0.8400
27	1.0000	0.9200

Table 5: Calculation of grey relation grade (GRG) by using the weight factor for Multiple Response characteristics

S.no	MRR	SR	Grade	Rank
1	0.3793	0.7576	0.5684	10
2	0.3554	0.4491	0.4023	27
3	0.3333	0.6637	0.4985	18
4	0.3468	0.9741	0.6604	5
5	0.3723	1.0000	0.6861	3
6	0.3726	0.6521	0.5124	14
7	0.3823	0.6521	0.5172	13
8	0.4012	0.6198	0.5105	15
9	0.3797	0.5725	0.4761	25
10	0.4953	0.4839	0.4896	21
11	0.4672	0.5102	0.4887	22
12	0.5012	0.4601	0.4806	24
13	0.4773	0.6198	0.5486	11

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14	0.5022	0.4777	0.4899	20
15	0.5222	0.8427	0.6825	4
16	0.5547	0.3333	0.4440	26
17	0.5879	0.6637	0.6258	6
18	0.5503	0.4237	0.4870	23
19	0.5959	0.4839	0.5399	12
20	0.6839	0.4545	0.5692	9
21	0.6120	0.3886	0.5003	17
22	0.6731	0.3456	0.5094	16
23	0.6166	0.6098	0.6132	7
24	0.6378	0.5475	0.5926	8
25	0.6477	0.3456	0.4966	19
26	0.6915	0.7576	0.7245	2
27	1.0000	0.8621	0.9310	1

Table 6: Response for grey relational Grade

Symbol	Parameters	Level1	Level2	Level3
A	Ton	0.116056	0.108511	0.163433
B	Toff	0.530456	0.5678	0.573444
C	WF	0.504167	0.588344	0.579189
D	WT	0.557267	0.549644	0.564789
E	SV	0.525078	0.534478	0.612144

Conclusion:

In this work the input parameters are pulse on time(T_{on}), pulse off time (T_{off}), wire tension(WT), wire feed(WF) and servo voltage(SV) and the output parameters are Material Removal Rate and Surface Roughness. The process is done by using the grey relational analysis using the Taguchi method and calculated the response for process parameters for stainless steel 310. The optimal combination of input parameters are A3B3C3D1E3 having the highest levels in the experimental run. So the MRR will be high and SR is low compared to other experimental runs.

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