OPTIMIZATION OF WEDM PROCESS PARAMETERS ON SS 317 USING GREY RELATIONAL ANALYSIS

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Abstract - *In the present study, Multi-objective optimization of Wire Electrical Discharge Machining parameters of SS 317 was performed using grey relational analysis which converts the multi responses into a single grade. Taguchi based L9 orthogonal array is used for plan of experiments. The objectives chosen are the Maximum Material removal rate and Minimum surface roughness using process parameters viz., pulse on time, pulse off time and Peak Current. The optimal machining parameters results better quality and removal rate.*

Key Words**: SS 317, Wire electric discharge machining, Multiobjective optimization, Grey relational analysis.**

1. INTRODUCTION

Need of advanced materials is increasing day to day for structural and engineering applications. Intense research of new Alloys and Composites [1-2] are going on for the requirement.

SS 317 stainless steel is developed primarily for higher strength and corrosion resistance by increasing nickel and molybdenum to the 316 stainless steel. At present, these steels are used as in different applications like desalination plants, valves & fittings, vessels, piping, fasteners, heat exchangers and construction materials as a replacement of austenitic stainless steels

Wire Electric Discharge Machining (WEDM) is a non-conventional machining process utilises thermal energy to machine electrically conductive parts with intricate shapes and hard material with high precision [3]. WEDM is adopted in many industries throughout the world which focused on fast machining with high surface finish and precision.

To achieve a sound and economical product, selection of most appropriate machining parameters are required for machining, for this industries applies various procedures and techniques to estimate the influence of the machining parameters on machining rate and surface quality, which are primary objectives. Machinist experiences are simple and inexpensive, but doesn't guarantees quality and functionality of product [4].

In the current scenario, optimization plays a vital role in organizations, industries and research to meet the demands of product with best quality with less price [5]. Taguchi method is used to optimize the single objective, but not suitable for the requirement of industries which has multi objectives for a single product [6]. Study of multiple objectives are still an interesting research area. Optimization of multiple objectives are more difficult and tedious compared to single objective optimization. To optimize multi-objective system into single objective, taguchi integrated grey relational analysis was performed and the optimal parameters were determined by using grey relational grade [7-8].

2. LITERATURE SURVEY

Raju et al. [9] studied the effect of Pulse on time, peak current, Servo voltage and wire tension on the surface roughness response on 316L SS using Full factorial design of experiments. It is observed that Pulse on time is the most significant factor that affects surface roughness (Ra), and the peak current, servo voltage and wire tension plays next to the pulse on time on characteristics respectively. Rajesh Khanna et al. [10] also studied and observed that Pulse off time has the most influent parameter on determining response characteristics of SS316.

Rajmohan et al. [11] investigated optimization of process parameters for surface roughness and MRR on SS 304L using taguchi integrated Grey relational analysis, and observed that Pulse off time is the most significant factor that affects the Grey relational grade and Grey relational analysis technique converts the multiple performance characteristics into single performance characteristic and therefore simplifies the optimization procedure. The accuracy can be improved by including more number of parameters and levels. Shunmuga Priyan et al. [12] observed that Pulse on, Pulse off, Servo Voltage and Wire feed has the effect on the Ra in the order on machining of SS 304 using GRA. Pulse off time has opposite effect to pulse on time. MRR decrease with increase of pulse off time, while surface roughness reduces.

Bharathi et al. [13] optimized the WEDM process parameters using additive law and observed that Pulse on time is significant factor that affects Ra, MRR and Kerf. Pulse on time, peak current, servo voltage and wire tension plays significant role in the characteristics respectively.

From the literature study, it is observed that none of the work has been carried out using SS 317. In the present investigation, an attempt is made to study and determine the optimal machining parameters of WEDM on SS 317 for minimum surface roughness and maximum material removal rate. Pulse on, Pulse off and Peak Current are chosen as the process parameters with a L9 array plan of experiments, to collect the experimental data and to analyse the effect of these parameters on surface roughness and material removal rate. Taguchi integrated Grey relational analysis is chosen for Multi-objective optimization.

3. EXPERIMENTAL DETAILS:

SS 317 is used as target material in the present investigation. Experiments were performed using Electronica Maxicut Wire EDM as shown in "Fig.1."

Fig -1 Wire Electric Discharge Machine

Fig -2 Material in Fixture

A 0.25 mm dia brass wire was used as an electrode to erode the metal under distilled water. A small gap of 0.025 mm to 0.05 mm is maintained in between the wire and work-piece. The size of the work piece considered for experimentation is 10 * 10 * 10 mm^3. The process parameters were being set in the WEDM machine and the experiments were conducted as per the plan in Table 2. The time required for material removal of workpiece is determined by using stopwatch and the surface roughness is determined by using talysurf instrument and the results were tabulated in Table 2.

In this experiment three process parameters are chosen which have more influence on material removal rate and surface roughness and each parameter is set at three levels. The parameters and its levels are shown in Table 1. L9 (3^{3-1} = 9 runs) orthogonal array of experiments was chosen for experimentation, instead of L 27 array (3^3 =27 runs) to reduce the experimentation cost.

Table 1. Process parameters and levels

Process parameters	Levels		
	Level-1	Level-2	Level-3
Pulse-on (µs)	8	9	10
Pulse-off (µs)	1	2	3
Pulse Current (A)	3	4	5

Table 2. Design of experiments and Responses

S.No	Pulse On A (µs)	Pulse off B (µs)	Pulse Current C (A)	MRR (mm^3/sec)	Ra (µ)
1	8	1	3	0.906	4.288
2	8	2	4	0.758	3.133
3	8	3	5	0.612	2.160
4	9	1	4	0.873	3.870
5	9	2	5	0.635	3.735
6	9	3	3	0.758	4.413
7	10	1	5	0.931	5.045
8	10	2	3	0.980	3.600
9	10	3	4	1.022	5.430

Fig -3: Specimens after machining.

3. MULTI OBJECTIVE OPTIMIZATION

3.1 Grey relational analysis:

Grey relational analysis (GRA) methodology is used to optimize the process parameters having multi-objectives through grey relational grade. The GRA methodology is as follows :

1. Conduct the experiments as per plan.
2. Normalize the responses.
3. Calculate the grey relational coefficients.
4. Calculate the grey relational grade by averaging the grey relational coefficient.

3.1.1 Normalization:

Convert the original sequences to a set of comparable sequences by normalizing the data. Depending upon the response characteristic, three main categories for normalizing the data is as follows:

'Larger the better' $$a_i^{(*)}(k) = \frac{b_i^{(*)}(k) - \min b_i^{(*)}(k)}{\max b_i^{(*)}(k) - \min b_i^{(*)}(k)} \quad (1)$$

'Smaller the better' $$a_i^{(*)}(k) = \frac{\max b_i^{(*)}(k) - b_i^{(*)}(k)}{\max b_i^{(*)}(k) - \min b_i^{(*)}(k)} \quad (2)$$

'Nominal the better' $$a_i^{(*)}(k) = 1 - \frac{b_i^{(*)}(k) - OV}{\max\{\max b_i^{(*)}(k) - OV, OV - \min b_i^{(*)}(k)\}} \quad (3)$$

3.1.2 Grey relational coefficient and grey relational grade

Grey relation coefficient (α_{ij}) is calculated for each of the performance characteristics, which expresses the relationship between ideal and actual normalized experimental results, as shown in "Eq.(4)."

$$\alpha_{ij} = \frac{\Delta\min + \xi\Delta\max}{\Delta oi(k) + \xi\Delta\max} \quad (4)$$

Grey relational grade can be calculated by taking the average of is the weighted grey relational coefficient and defined as follows

$$\Sigma\beta_k \gamma(x_0^{(*)}(k), x_i^{(*)}(k)) = 1 \quad (5)$$

Table -3: Grey Relational Grades

Expt. No	MRR (mm³/sec)	Ra (µm)	Normalized values		Grey Relational Coefficients		Grey Relational Grades
			MRR	Ra	MRR	Ra	
1	0.906	4.288	0.7157	0.3494	0.637	0.435	0.536
2	0.758	3.133	0.3545	0.7023	0.436	0.627	0.532
3	0.612	2.160	0.0000	1.0000	0.333	1.000	0.667
4	0.873	3.870	0.6348	0.4771	0.578	0.489	0.533
5	0.635	3.735	0.0569	0.5183	0.346	0.509	0.428
6	0.758	4.413	0.3545	0.3112	0.436	0.421	0.429
7	0.931	5.045	0.7773	0.1177	0.692	0.362	0.527
8	0.980	3.600	0.8974	0.5596	0.830	0.532	0.681
9	1.022	5.430	1.0000	0.0000	1.000	0.333	0.667

4. ANALYSIS OF VARIANCE

ANOVA was performed to identify the process parameters that significantly affect the time and quality. This is accomplished by separating the total variability of the grey relational grades, which is measured by the sum of the squared deviations from the total mean of the grey relational grade, into contributions by each machining process parameters and the error. An ANOVA table consists of sums of squares, corresponding degrees of freedom, the F-ratios, and the contribution percentages of the machining factors. These contribution percentages can be used to assess the importance of each factor for the interested grades.

Table - 4: Analysis of Variance

Source	DF	Seq SS	Adj SS	F - Value	P- Value	%Contribution
Pulse on	2	0.041539	0.020769	1.57	0.388	55.16%
Pulse off	2	0.004978	0.002489	0.19	0.841	6.62%
Pulse Current	2	0.00223	0.001115	0.08	0.922	2.96%
Error	2	0.026378	0.013189	--	--	35.11%
Total	8	0.075124	--	--	--	

The relative effect among the control factors for the Grey relational grades can be verified by using the ANOVA so that the optimal combinations of the machining factors can be accurately determined. From Table 4, it is also evident that the control factors Pulse on, Pulse off and Pulse Current has the most % of contribution in the descending order on the Grey relational grades.

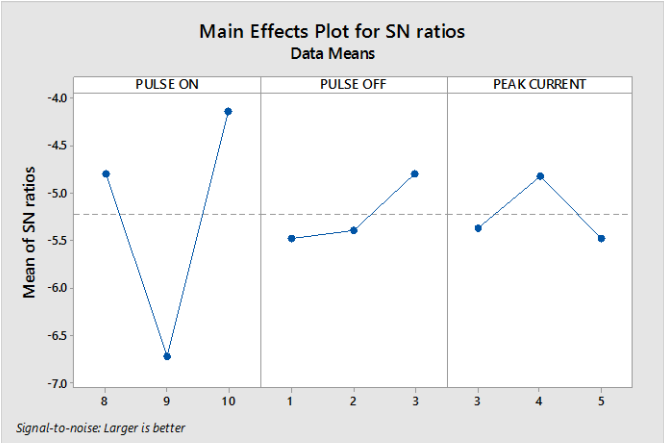

Fig -4: S/N ratio – Grey relational grades.

5. CONFIRMATION RUN:

After determining the optimal combination of parameters, the last phase is to verify the MRR, surface roughness by conducting the confirmation experiment. The $A_3B_3C_2$ is an optimal parameter combination of the machining process by Grey relational analysis. The confirmation test is carried out with the optimal parameter combination $A_3B_3C_2$, and the results are tabulated in Table.5 and the grey relational grade is increased by 30%. It is clear that the MRR and SR increased greatly with the optimal parameters.

Table 5. Confirmation test results

Type	Initial	Optimal/Predicted	Experimental
Level combination	$A_1B_3C_3$	$A_3B_3C_2$	$A_3B_3C_2$
MRR (mm^3/sec)	0.612	0.8872	0.855
SR (µm)	2.16	2.12	2.3
GRG	0.667	0.93	0.94

Conclusions:

- The effect of process parameters i.e. pulse on-time, pulse off-time, Pulse current on response variables such as material removal rate, surface roughness has been thoroughly studied. The levels of significance of process parameters for each response variable has been investigated using ANOVA.
- Pulse on time found to be the most significant factors influencing all responses investigated for both the experiment sets.
- The $A_3B_3C_2$ is an optimal parameter combination of the machining process by Taguchi based Grey relational analysis.
- The grey relational grade is increased by 30%. It is clear that the MRR and SR increased greatly with the optimal parameters.

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