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[1] P. SREERAJ, [2] T. KANNAN, [3] Subhasis MAJI

OPTIMIZATION OF HEAT AFFECTED ZONE IN SUBMERGED ARC WELDING PROCESS USING GREY-BASED TAGUCHI APPROACH

[1] Department of Mechanical Engineering, YOUNUS College of Engineering Technology, Kerala, INDIA
[2] SVS College of Engineering, Coimbatore, Tamilnadu, INDIA
[3] Department of Mechanical Engineering IGNOU, Delhi, INDIA

Abstract: Optimization of submerged arc welding (SAW) process parameters was carried out to obtain optimal parametric combination to yield favourable heat affected zone and weld bead geometry in mild steel plates IS 2062. Taguchi's L_{25} orthogonal array (OA) design and signal- to- noise ratio (S/N ratio) have been used in this study. Penetration (P), bead width (W), reinforcement (R) and heat affected zone (HAZ) are selected as objective functions. The Taguchi method followed by Grey relational analysis has been applied to solve this multi response optimization problem. The developed models have checked for adequacy and significance based on ANOVA test. Accuracy of optimization was confirmed by conducting confirmation tests. Results indicate feasibility of Grey relational analysis in continuous improvement in welding industry.
Keywords: SAW, ANOVA, Taguchi's concept, orthogonal array, HAZ

1. INTRODUCTION

Submerged arc welding is a multi-factor, multi-objective manufacturing process. Because of easy control of process variables, high quality, deep penetration and smooth finish, it is widely preferred in fabrication industry. In the present work, the effect of voltage, current, welding speed and nozzle to plate distance on bead geometry and heat affected zone (HAZ) have been studied. Mechanical and chemical properties of good weld depend on bead geometry and HAZ. Bead geometry has a direct effect on process parameters. So it is necessary to study the relationship between process parameters and weld bead geometry [1].

Fig 1 shows the weld bead geometry. Mechanical strength of weld metal is highly influenced by the composition of metal but also by weld bead shape. This is an indication of bead geometry. It mainly depends on welding current, welding speed and arc voltage etc. Therefore it is necessary to study the relationship between in process parameters and bead parameters to study weld bead geometry. This paper highlights the study carried out to develop mathematical models to optimize weld bead geometry and HAZ, on bead on plate welding by SAW.

Heat affected zone of a fusion weld in steel is divided into three zones namely supercritical, inter critical and subcritical .The super critical region is further divided into two regions such as grain growth and grain refinement. The microstructure of grain growth and grain refinement regions of HAZ's super critical zone influence the properties of welded joint. Heat input from welding cycle must be limited so as to keep the width of supercritical zone as narrow as possible. So the size of HAZ is an indication of structural changes and it is controlled by process variables and heat input. Mathematical models are developed to correlate the process variables and to optimize the size of the weld bead's HAZ in order to obtain a better quality weld.

In this study Taguchi method and grey relational analysis is used for solving the multi optimization problem. This method utilizes a well balanced experimental design with limited number of experimental runs called orthogonal array (OA) and signal to noise ratio (S/N ratio) which serve the objective function to be optimized, within experimental domain. The traditional Taguchi method cannot solve multi-objective optimization problems. In order to overcome this difficulty, the Taguchi method coupled with grey relational analysis used to solve the optimization problem in this study.

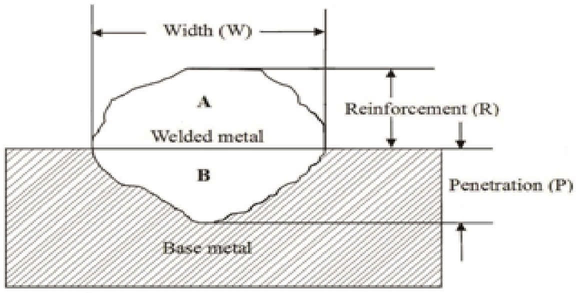

Figure 1: weld bead geometry

2. TAGUCHI METHOD

Taguchi method uses a special type of design of orthogonal arrays (OA) to study the entire parameter space with smaller number of experiments. The experimental results are then transferred to signal- to- noise (S/N) ratio. This ratio can be used to measure the quality characteristics deviating from desired values. Usually there are three categories of in the analysis of the signal-to-noise ratio, that is the lower- the- better, higher- the- better and nominal- the-better. Regardless of category of quality characteristics larger signal –to-noise ratio corresponds to the better quality characteristics. The optimal process parameters are the levels with highest signal–to-noise ratio [2]. ANOVA tests are performed to see the process parameters are statically significant. Finally a confirmation experiment is conducted to verify the optimal process parameters.

3. GREY RELATIONAL ANALYSIS

3.1. Data processing

In Grey relational analysis, experimental data are first normalised from zero to one. This process is known as Grey relational generation. Based on the normalised data, Grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Overall Grey relational grade is determined by averaging the Grey relational coefficient corresponding to selected responses. The overall performance characteristics of the multiple responses process depends on the calculated Grey relational grade. This process converts a multiple response process optimization problem with objective function as Grey relational grade. The optimal parametric combination is then evaluated which would result highest grey relational grade [3].

In Grey relational generation, Normalized bead width, reinforcement and heat affected zone (HAZ), corresponding to lower-the –better (LB) criterion can be termed as

$$x_i(k) = \frac{\max y_i(k) - y_i(k)}{\max y_i(k) - \min y_i(k)} \quad (1)$$

Bead penetration should be the larger the better and is expressed as

$$x_i(k) = \frac{y_i(k) - \min y_i(k)}{\max y_i(k) - \min y_i(k)} \quad (2)$$

where $x_i(k)$ is the value after the grey relation generation, min $y_i(k)$ is the smallest value of $y_i(k)$ for kth response, and max $y_i(k)$ is the largest value of $y_i(k)$ for kth response. The normalized data after Grey relational generation are tabulated in Table 5. An ideal sequence is $x_0(k)$ where k=1, 2, 3....25, for the responses. The definition of Grey relational grade in the course of grey relational analysis is to reveal the degree of relation between the 25 sequences [$x_0(k)$ and $x_i(k)$, i=1,2,3....25]. The grey relational coefficient:

$$\xi_i(k) = \frac{\Delta_{min} + \psi\Delta_{max}}{\Delta_{0i}(k) + \psi\Delta_{max}} \quad (3)$$

where $\Delta_{0i} = \|x_0(k) - x_i(k)\|$ is the difference of the absolute value $x_0(k)$ and $x_i(k)$;ψ is the diminishing coefficient $0 \le \psi \le i$; $\nabla_{min} = \forall j^{min}\ \square i \forall k^{min} \|x_0(k) - x_i(k)\|$ is the smallest value of Δ_{0i}; and

$\Delta_{max} = \forall j^{max} \; \square i \; \forall k^{max} \| x_0(k) - x_i(k) \|$ = largest value of Δ_{0i}. After averaging the Grey relational coefficients, the grey relational grade γ_i can be calculated as:

$$\gamma_i = \frac{1}{n} \sum_{k=1}^{n} \xi_i (k) \qquad (4)$$

where n is the number of process responses. The higher value of grey relational grade corresponds to intense relational degree between sequence $x_0(k)$ and the given sequence $x_i(k)$. It means that higher grey relational grade it is closer to the optimal point [4].

4. SUBMERGED ARC WELDING PROCESS

Submerged arc welding is a multi objective, multifactor welding technique. In submerged arc welding process, instead of a flux covered electrode granular flux and bare electrodes are used. The flux is served as a shield and protects the molten weld pool from atmospheric condition.

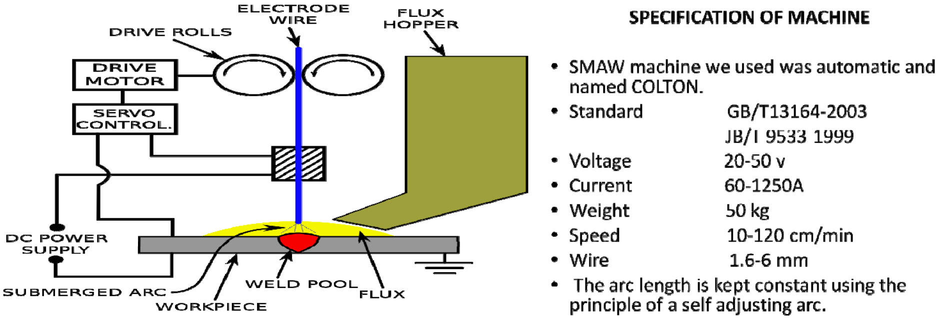

Figure 2: Schematic diagram of SAW

5. EXPERIMENTATION

The experiment was designed based on Taguchi's method. The experiment was conducted as per L_{25} orthogonal array using COLTON submerged arc welding equipment (SAW) at Younus College of engineering and technology, kollam, India and specification of machine is shown above. Welding was done on bead on plate with grade IS 2062 carbon steel. Test plates of size 300 x 200 x 10 mm were cut from mild steel plate of and one of the surfaces is cleaned to remove oxide and dirt before welding EH 14 wire of 4 mm diameter in the form of coil and EASAB granular flux was used for welding. The flux is heated for two hours at 200 ^{0}C.The chemical composition of filler wire and base metal is shown in Table 1. Table 2 shows welding parameters and their levels.Two transverse specimens were cut from each weldment and standard metallographic procedures were adopted. Bead profiles were drawn using a reflective type profile projector [5].

Table 1: Chemical Composition of Base Metal and Filler Wire

	Elements, Weight %								
Materials	C	Si	Mn	P	S	Al	Cr	Mo	Ni
IS 2062	0.150	0.160	0.870	0.015	0.016	0.031	-	-	-
EH 14	0.12	0.1	0.172	0.03	0.03	-	-	-	-

Table 2: Welding Parameters and their Levels

Parameters	Factor Levels						
	Unit	Notation	1	2	3	4	5
Welding Current	A	I	350	420	500	580	650
Welding Speed	mm/min	S	30	40	50	60	70
Voltage	v	V	24	26	28	30	32
Nozzle to plate distance	mm	T	30	32.5	35	37.5	40

6. PLAN OF INVESTIGATION

The research work is carried out in the following steps.

1. Identifying the quality characteristics and process parameters to be evaluated.
2. Determine the number of levels for the process parameters and possible interactions between process parameters.
3. Select appropriate orthogonal array and assign process parameters to the orthogonal array.
4. Conduct experiment as per arrangement of orthogonal array.
5. Analyse the experiments through Grey–based Taguchi approach.
6. Select the optimum level of process parameters
7. Conduction of confirmation experiment

6.1. Development of orthogonal array

The experimental design based on an orthogonal array is orthogonal. It allows the effect of each welding process parameters at different levels to be separated out. To select appropriate orthogonal array appropriate degrees of freedom must be selected. The degrees of freedom are defined as the number of comparisons between process parameters that must be able to determine which level is better and specifically how much better is [6]. Once degrees of freedom are known next step is to select appropriate orthogonal array to fit the specific task. The degrees of freedom for the orthogonal array should be greater than or at least equal to, those for the process parameters. In this study L_{25} orthogonal array with 8 columns and 18 rows was used. This is shown in Table 3.

Table 3: Orthogonal array

Trial Number	Design Matrix			
	I	S	V	T
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	1	5	5	5
6	2	1	2	3
7	2	2	3	4
8	2	3	4	5
9	2	4	5	1
10	2	5	1	2
11	3	1	3	5
12	3	2	4	1
13	3	3	5	2
14	3	4	1	3
15	3	5	2	4
16	4	1	4	2
17	4	2	5	3
18	4	3	1	4
19	4	4	2	5
20	4	5	3	1
21	5	1	5	4
22	5	2	1	5
23	5	3	2	1
24	5	4	3	2
25	5	5	4	3

I - Welding current; S - Welding speed; N –Stick out; T –Nozzle to plate distance; V –voltage

6.2. Conducting experiments as per orthogonal array

In this work twenty five experimental run were allowed as per the orthogonal array for the estimation of parameters on bead geometry as shown Table 3 at random. At each run settings for all parameters were disturbed and reset for next deposit [7]. This is very essential to introduce variability caused by errors in experimental set up. The experiments were conducted at YOUNUS College of Engineering and Technology, Kollam, 691010, India.

6.3. Recording of Responses

For measuring the clad bead geometry, the transverse section of each weld overlays was cut using band saw from mid length. Position of the weld and end faces were machined and grinded. The specimen and faces were polished and etched using a 5% nital solution to display bead dimensions [8]. The clad bead profiles were traced using a reflective type optical profile projector at a magnification of X10, in YONUS College of engineering and Technology, Kollam.

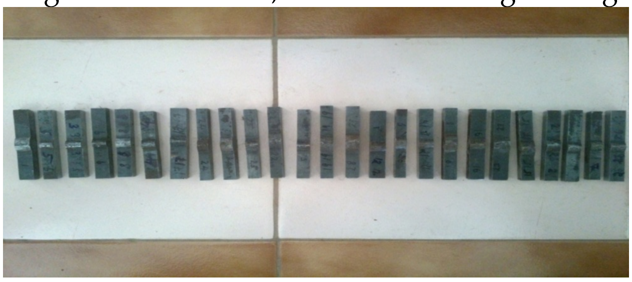

Figure 3: Sample specimens

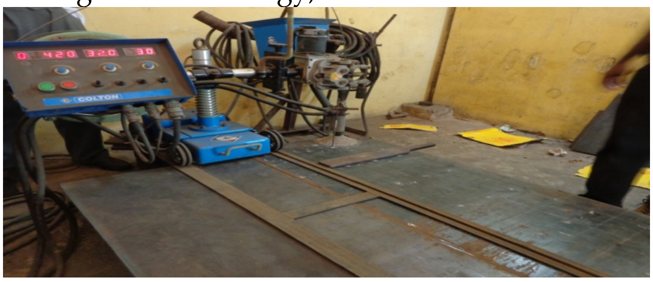

Figure 4: SAW machine

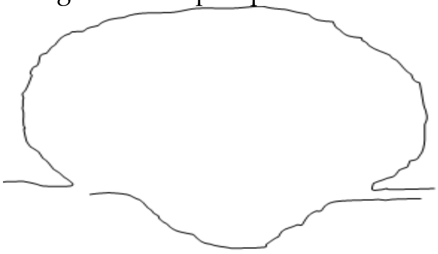

Figure 5: Traced Profile of bead geometry

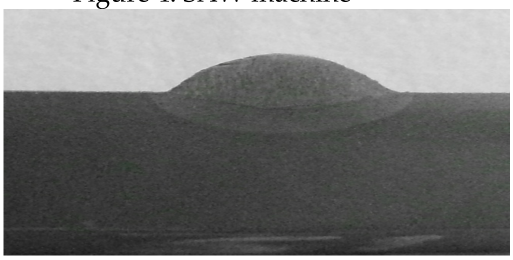

Figure 6: Welded specimen

Then the bead dimension such as depth of penetration height of reinforcement and clad bead width were measured. The profiles traced using AUTO CAD software. This is shown in Fig 3, shows SAW method. This represents profile of the specimen (front side). The weld specimen is shown in Fig. 5. Fig 6 shows sample welded specimen.The measured weld bead dimensions and percentage of dilution is shown in Table 4.

Table 4: Orthogonal array and Observed Values of Clad Bead Geometry

Trial No.	Design Matrix				Bead Parameters			
	I	S	V	T	W (mm)	P (mm)	R (mm)	HAZ (mm)
1	1	1	1	1	18.567	3.202	4.817	2.623
2	1	2	2	2	16.664	3.625	4.929	2.193
3	1	3	3	3	13.532	4.360	5.231	3.012
4	1	4	4	4	12.583	4.341	5.256	2.345
5	1	5	5	5	12.743	4.306	5.102	2.432
6	2	1	2	3	15.649	2.529	4.513	2.340
7	2	2	3	4	15.792	3.532	4.304	4.152
8	2	3	4	5	14.641	2.530	4.912	2.548
9	2	4	5	1	12.781	3.821	4.786	2.177
10	2	5	1	2	23.684	4.234	8.112	4.340
11	3	1	3	5	12.912	3.015	3.534	4.761
12	3	2	4	1	13.743	3.267	3.098	2.666
13	3	3	5	2	12.861	3.561	4.120	3.056
14	3	4	1	3	21.543	4.812	7.386	2.712
15	3	5	2	4	22.612	3.712	7.814	1.993
16	4	1	4	2	12.012	2.531	3.253	2.388
17	4	2	5	3	12.631	2.501	3.746	2.327
18	4	3	1	4	22.902	3.561	5.910	2.405
19	4	4	2	5	21.231	3.505	6.265	2.213
20	4	5	3	1	18.236	3.587	7.545	2.780
21	5	1	5	4	10.438	2.419	2.698	1.912
22	5	2	1	5	23.760	3.619	5.210	2.223
23	5	3	2	1	21.194	3.921	5.634	2.461
24	5	4	3	2	19.523	3.525	6.021	2.102
25	5	5	4	3	17.091	3.501	5.204	1.918

W-Width; R - Reinforcement W - Width; P - Penetration; D - Dilution %

Table 5: Experimental Data

Bead Parameters			
W (mm)	P (mm)	R (mm)	HAZ (mm)
18.567	3.202	4.817	2.623
16.664	3.625	4.929	2.193
13.532	4.360	5.231	3.012
12.583	4.341	5.256	2.345
12.743	4.306	5.102	2.432
15.649	2.529	4.513	2.340
15.792	3.532	4.304	4.152
14.641	2.530	4.912	2.548
12.781	3.821	4.786	2.177
23.684	4.234	8.112	4.340
12.912	3.015	3.534	4.761
13.743	3.267	3.098	2.666
12.861	3.561	4.120	3.056
21.543	4.812	7.386	2.712
22.612	3.712	7.814	1.993
12.012	2.531	3.253	2.388
12.631	2.501	3.746	2.327
22.902	3.561	5.910	2.405
21.231	3.505	6.265	2.213
18.236	3.587	7.545	2.780
10.438	2.419	2.698	1.912
23.760	3.619	5.210	2.223
21.194	3.921	5.634	2.461
19.523	3.525	6.021	2.102
17.091	3.501	5.204	1.918

Table 6. Grey relational generation

Bead Parameters			
W (mm)	P (mm)	R (mm)	HAZ (mm)
0.392755	0.327204	0.608607	0.750439
0.536681	0.50397	0.58792	0.901369
0.773559	0.811116	0.532139	0.6139
0.845334	0.803176	0.527521	0.81748
0.833232	0.78855	0.555966	0.849772
0.613447	0.045967	0.664758	0.213759
0.602632	0.465107	0.703362	0.776764
0.689684	0.046385	0.59106	0.906985
0.830358	0.585875	0.614333	0.147771
0.005748	0.758462	0	0
0.820451	0.24906	0.845586	0.735346
0.757601	0.354367	0.926117	0.598456
0.824308	0.477225	0.737348	0.7192
0.167675	1	0.134097	0.971569
0.086825	0.540326	0.055042	0.832924
0.888519	0.046803	0.897488	0.854335
0.841703	0.034267	0.806428	0.826957
0.064892	0.477225	0.406723	0.894349
0.191272	0.453824	0.341153	0.695332
0.417789	0.48809	0.104728	1
1.007563	0	1	0.890839
0	0.501463	0.536018	0.807301
0.19407	0.627664	0.457702	0.93331
0.320451	0.462181	0.386221	0.997894
0.504387	0.452152	0.537126	0.997894

7. OPTIMIZATION OF SAW PROCESS

7.1. Evaluation of optimal process condition

Experimental data have been normalised first, that is Grey relational generation. The normalised data is shown in Table 4. For bead width, reinforcement and dilution lower-the-better (LB) and for depth of penetration higher-the better (HB) criterion has been selected. Grey relational coefficients for each performance characteristics have been calculated using equation 3 and shown in Table 6. These Grey relational coefficients for each response has been accumulated to evaluate Grey relational grade by equation 4 which is the overall representative of all features of weld quality , shown in Table 8. Thus using a combination of Taguchi approach and grey relational analysis multi criteria optimization problem has been transformed in to a single equivalent objective function. Higher the value of Grey relational grade, the corresponding factor combination is said to be close to optimal [9]. The mean response table for the overall Grey relational grade is shown in

Table 9 and is represented graphically in Figure 1. The overall Grey relational grade is calculated using larger-the-better criterion using equation 5.

$$SN\ (Larger\text{-}the\text{-}better) = -10 \log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \quad (5)$$

where n is the number of measurements and y_i is the measured characteristic value. For orthogonal experimental design, it is possible to separate out the effect of each welding parameter at different levels. The mean grey relational grade ratio for each level of the other parameters computed in similar manner shown in Table 9. Total mean Grey relational grade is the average of all entries shown in Table 8. With the help of Figure 1, the optimal parametric combination has been determined as $I_2S_1V_5T_4$.

Table 7: Evaluation of Δ_{0i} for each response

Bead Parameters			
W (mm)	P (mm)	R (mm)	HAZ (mm)
0.607245	0.672796	0.391393	0.249561
0.463319	0.49603	0.41208	0.098631
0.226441	0.188884	0.467861	0.3861
0.154666	0.196824	0.472479	0.18252
0.166768	0.21145	0.444034	0.150228
0.386553	0.954033	0.335242	0.786241
0.397368	0.534893	0.296638	0.223236
0.310316	0.953615	0.40894	0.093015
0.169642	0.414125	0.385667	0.852229
0.994252	0.241538	1	1
0.179549	0.75094	0.154414	0.264654
0.242399	0.645633	0.073883	0.401544
0.175692	0.522775	0.262652	0.2808
0.832325	0	0.865903	0.028431
0.913175	0.459674	0.944958	0.167076
0.111481	0.953197	0.102512	0.145665
0.158297	0.965733	0.193572	0.173043
0.935108	0.522775	0.593277	0.105651
0.808728	0.546176	0.658847	0.304668
0.582211	0.51191	0.895272	0
-0.00756	1	0	0.109161
1	0.498537	0.463982	0.192699
0.80593	0.372336	0.542298	0.06669
0.679549	0.537819	0.613779	0.002106
0.495613	0.547848	0.462874	0.002106

Table 8: Grey relational coefficient of each performance characteristics (with ψ=.5)

W (mm)	P (mm)	R (mm)	HAZ (mm)
0.451571	0.426332	0.56092	0.667057
0.519039	0.501993	0.548198	0.835239
0.688287	0.725812	0.516603	0.56427
0.763748	0.717541	0.51415	0.732579
0.749886	0.70279	0.529642	0.768961
0.563982	0.343871	0.598629	0.38873
0.557185	0.483142	0.627638	0.691337
0.617043	0.34397	0.550091	0.843149
0.746668	0.546971	0.564546	0.36976
0.334616	0.674274	0.333333	0.333333
0.735782	0.399699	0.764042	0.65389
0.673492	0.43644	0.871258	0.554604
0.739982	0.488866	0.655607	0.640369
0.375284	1	0.366058	0.946197
0.353813	0.52101	0.346031	0.74954
0.817687	0.344069	0.829859	0.774395
0.759536	0.341126	0.720906	0.742894
0.348406	0.488866	0.457341	0.825558
0.38205	0.477931	0.431463	0.621374
0.462017	0.494115	0.358353	1
1.015358	0.333333	1	0.820801
0.333333	0.500733	0.518682	0.721814
0.382869	0.573174	0.479709	0.882317
0.423891	0.48178	0.448922	0.995806
0.502203	0.477168	0.519279	0.995806

Table 9: Gery relational grade

Expt No.	GRG
1	0.52647
2	0.601117
3	0.623743
4	0.682005
5	0.68782
6	0.473803
7	0.589826
8	0.588563
9	0.556986
10	0.418889
11	0.638353
12	0.633949
13	0.631206
14	0.671885
15	0.492599
16	0.691503
17	0.641116
18	0.530043
19	0.478205
20	0.578621
21	0.792373
22	0.518641
23	0.579517
24	0.5876
25	0.623614

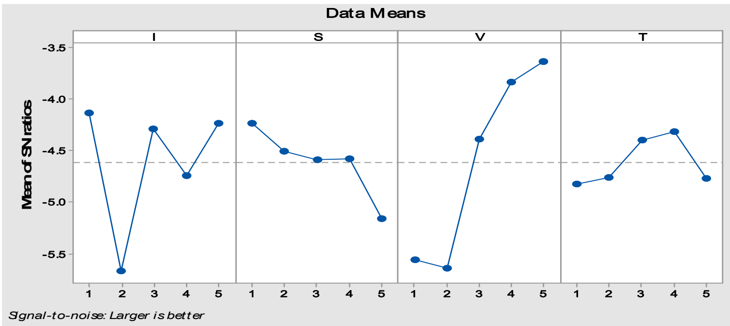

Figure 7: Main effects of S/N ratios

8. ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA) technique was used to test the adequacy of the model. This method is very useful to reveal the level of significance of influence of factors or interaction factors on particular response. It separates the total variability of responses into contributions rendered by each of parameter and error [10]. Table 10 shows analysis of variance and Table 11 shows response table.

$$SS_T = SS_F + SS_e \quad (6)$$

where $SS_T = \sum_{j=1}^{p}(\gamma_j-\gamma_m)^2$, SS_T =Total sum of squared deviations about the mean, SS_F=Sum of squared deviations due to each other, SS_e=Sum of squared deviations due to error, γ_j=Mean response for *jth* experiment, γ_m=Grand mean of responses.

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In ANOVA table mean square deviation is defined as:

$$MS = \frac{Ss\ (sum\ of\ squared\ deviation)}{DF\ (Degree\ of\ freedom)} \qquad (6)$$

F-value of Fishers F ratio (variance ratio) is defined as:

$$F = \frac{MS\ for\ a\ term}{MS\ for\ the\ error\ term} \qquad (7)$$

Depending on F-value, P-value (probability of significance is calculated If P value is 95% confidence level then factors are significant.

Table 10: Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
I	1	0.001276	0.001276	0.30	0.587
S	1	0.008447	0.008447	2.01	0.171
V	1	0.070804	0.070804	16.88	0.001
T	1	0.001045	0.001045	0.25	0.623
Error	20	0.083910	0.004195		
Total	24	0.165482			

Table 11: Response Table for Signal to Noise Ratio

Level	I	S	V	T
1	-4.134	-4.237	-5.560	-4.821
2	-5.664	-4.506	-5.641	-4.760
3	-4.292	-4.591	-4.391	-4.401
4	-4.748	-4.	-3.839	-4.319
5	-4.237	-5.162	-3.643	-4.773
Delta	1.530	0.926	1.999	0.502
Rank	2	3	1	4

9. VALIDATION OF MODELS

The estimated Grey relational grade $\hat{\gamma}$ using the optimal level of design parameters can be calculated as:

$$\hat{\gamma}=\gamma_m+\sum_{i=1}^{o}(\hat{\gamma}_i-\gamma_m) \qquad (9)$$

where γ_m is the total mean Grey relational grade, $\hat{\gamma}_i$ is the mean Grey relational grade at the optimal level and o is the number of the main design parameters that affect the quality characteristics. This means that the predicted Grey relational grade is equal to the mean grey relational grade plus the summation of the difference between overall mean Grey relational grades for each of the factors at optimum level.

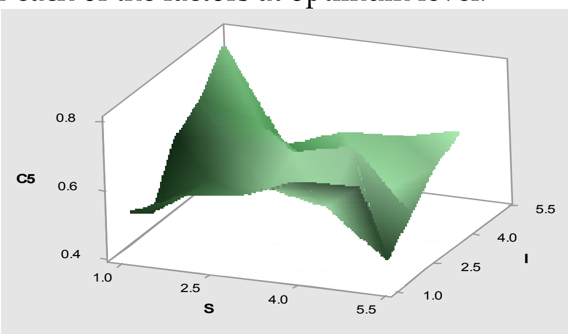

Figure 8: Interaction plot for GRG and I and S

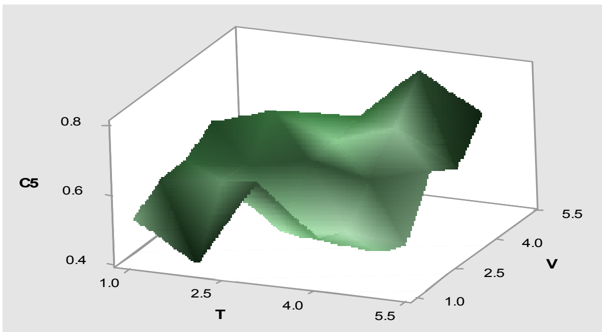

Figure 9: Interaction plot for GRG and V and T

Table 12: Results of conformity experiment

Parameters	Initial factor setting	Prediction	Experiment
Level of factors	$I_1 S_1 V_1 T_1$	$I_2 S_1 V_5 T_4$	$I_1 S_1 V_5 T_4$
Bead width	18.567		8.225
Penetration	3.202		1.347
Reinforcement	4.817		2.785
HAZ	2.627		1.8170
Overall Grey relational grade	0.52641	0.67032	0.789597
Improvement in grey relational grade = 0.16			

Table 12 represents the comparison of the predicted bead geometry parameters with that of actual by using optimal welding conditions; good agreement between the two has been observed and improvement of overall Grey relational grade is the result. This proves the utility of the proposed approach in relation to process optimization, where more than one objective has to be fulfilled simultaneously.

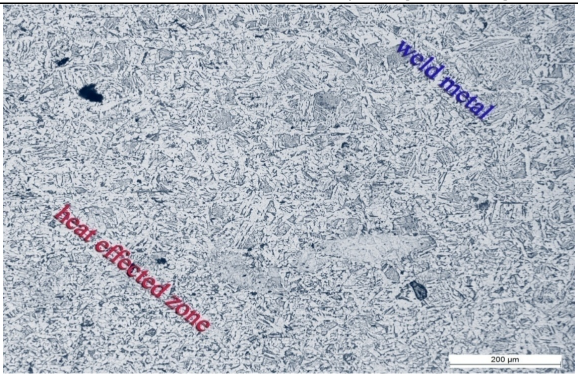

Figure 10: Heat affected zone

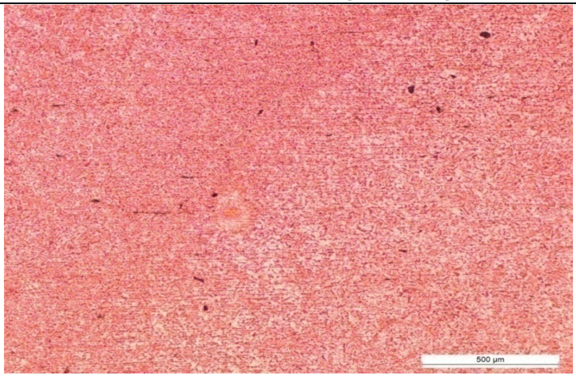

Figure 11: Microstructure of fusion zone with impurities

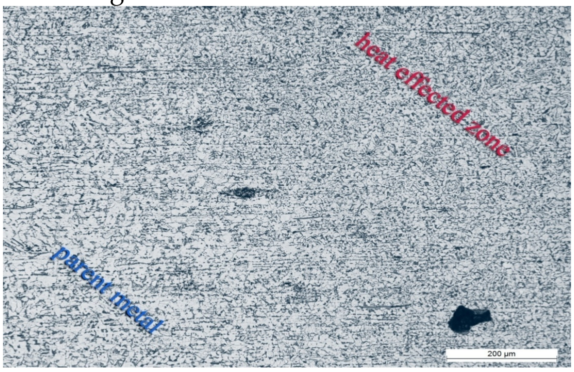

Figure 12: parent metal and HAZ

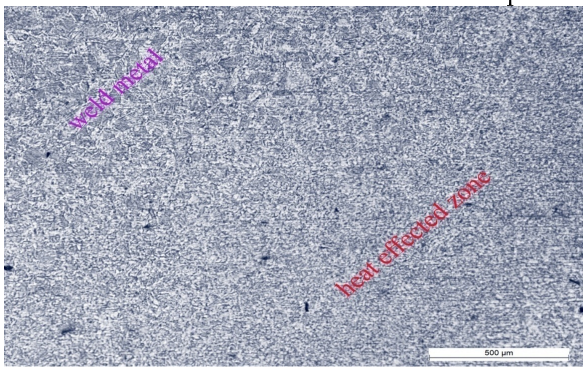

Figure 13: Micro structure of HAZ

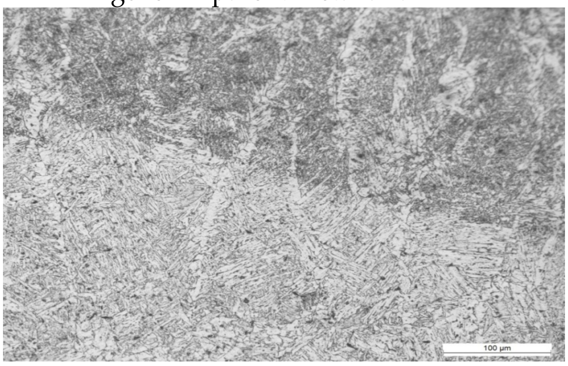

Figure 14: Fusion line

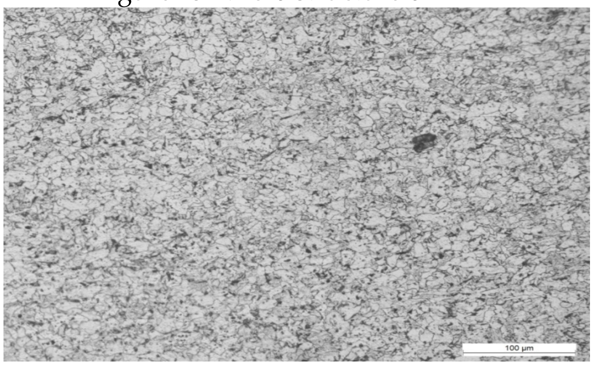

Figure 15: Microstructure of weld zone

10. RESULTS AND DISCUSSIONS

In the Grey based Taguchi method only performance feature is Grey relational grade and the main aim should be to reach a parameter setting that can achieve the highest overall Grey relational grade. The Grey relational grade is the representative of all individual performance characteristics. From conformity experiments shown in Table 12. It can be shown that there is overall improvement in Grey relational grade by 0.10.From ANOVA Table 12 it is seen that most insignificant factor affecting is stick out. Table 11 shows response to signal noise ratios. Fig 8 shows the surface plot for grey relational grade with S and I. Fig 9 shows surface plot for grey relational grade with I and N. Figures 10-15 shows micro structures of wed zone and fusion line.

11. CONCLUSION

In this study, a detailed methodology of Taguchi optimization technique coupled with Grey relational analysis has been presented for evaluating the bead geometry, HAZ and parametric combinations in submerged arc welding process. For achieving optimal parametric combination in order to get deeper penetration, minimum bead height, bead width and HAZ of the weldment produced by submerged arc welding. Taguchi method is very popular and efficient method for optimization that can be performed with limited number of runs. The study has intended to prove the efficient of Grey based Taguchi method for solving multi objective optimization problem in the field of submerged arc welding.

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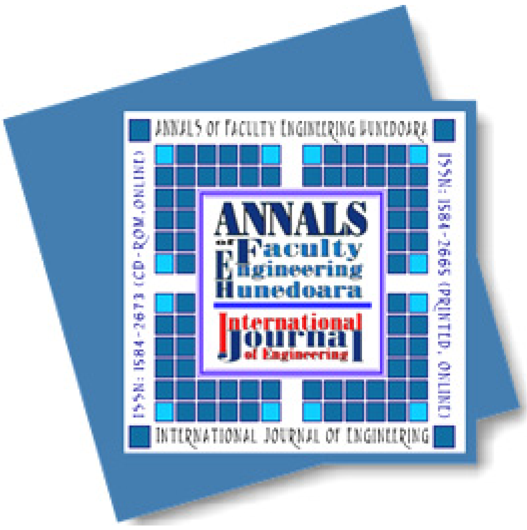
REFERENCES

[1.] Kannan, T.; Murugan, N. (2006). Effect of flux cored arc welding process parameters on duplex stainless steel clad quality, Journal of Material Processing Technology, vol.176, pp 230-239.
[2.] Ugur Esme; Melih Bayramoglu; Yugut Kazanancoglu; Sueda Ozgun (2009). Optimization of weld bead geometry in TIG welding process using Grey relational analysis and Taguchi method, Materials and technology, Vol.43, pp 143-149.
[3.] Jagannatha, N.; Hiremath, S.S; Sadashivappa, K (2012).Analysis and parametric optimization of abrasive hot air jet machining for glass using Taguchi method and utility concept, International Journal of Mechanical and materials engineering, Vol. 7, pp. 9 – 15, No.1.9.15.
[4.] Norasiah Muhammed; Yupiter HP Manurung; Muhammed Hafidzi (2012) Optimization and modelling of spot welding parameters with simultaneous response consideration using multi objective Taguchi method and utility concept. Journal of Mechanical science and Technology, Vol.26 (8), pp. 2365 - 2370.
[5.] Thakur, A.G; Nandedkar, V.M (2010) Application of Taguchi method to determine resistece spot welding conditions of austenitic stainless steel AISI 304, Journal of scientific and industrial research, Vol- 69, pp 680-683.
[6.] Tarng, Y.S; Yang;W.H (1998) Optimization of weld bead geometry in gas tungsten arc welding by the Taguchi method , International Journal of Advanced Manufacturing Technology, Vol-14, pp 549-554.
[7.] Saurav Datta; Ashish Bandyopadhyay; Pradip Kumar Pal (2008). Grey based Taguchi method for optimization of bead geometry in submerged arc bead on plate welding, International Journal of Advanced Manufacturing Technology, Vol-39, pp 1136-1143.
[8.] Gunaraj, V.; Murugan, N. (1999). Prediction and comparison of the area of the heat effected zone for the bead on plate and bead on joint in SAW of pipes, Journal of Material processing Technology, Vol. 95, pp. 246 - 261.
[9.] Katherasan, D; Madana Sashikant; P; Sathiya, P (2012). Flux cored arc welding parameter optimization of AISI 316L (N) austenitic stainless steel, World academy of science, Engineering and Technology, Vol.6 pp. 635-642
[10.] U. Esme A. Kokangul; Bayramoglu; M, Green, M; (2009). Mathematical modelling for prediction and optimization of TIG welding pool geometry, Metalurgija, Vol (48), pp 109-112.



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