International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 2, Issue 1 (jan-feb 2014), PP. 08-11

OPTIMIZATION OF WELD BEAD GEOMETRICAL PARAMETERS FOR BEAD ON PLATE SUBMERGED ARC WELDS DEPOSITED ON IS-2062 STEEL USING TAGUCHI METHOD

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Abstract—**This paper details the application of Taguchi techniques to determine the optimal process parameters for submerged arc welding (SAW).The planned experiment work is conducted in the semiautomatic submerged arc welding machine and signal to noise ratios have been computed .the contribution of each factor has been validated by analysis of variance(ANOVA). The results of the present investigation indicate that the welding voltage is the most significant parameter that controls the bead penetration as compared to other controlling parameters. The contribution of voltage, current welding speed and nozzle-to-plate distance have been found to be respectively: 60.8%, 9.86%, 3.54% and 13.8%. Optimum results have been obtained by using 26v, 475A at a trolley speed of 0.25 m/min and NPD of 16 mm.**

Keywords— **Submerged arc welding, Taguchi method, ANOVA, IS – 2062 steel, Signal to noise ratio.**

I. INTRODUCTION

Mechanical properties of submerged Arc welds (SAW) largely depend upon the weld bead geometrical parameters such as weld width, depth of penetration and reinforcement height. Prediction of SAW process parameters is a very complex process. Many investigators [3-7] have tried to correlate the process parameters with the weld bead which geometrical shape characteristics result into high strength and high quality welds.

Purohit [8] has determined bead geometry parameters for metal inert gas (MIG) underwater welded bead-on-plates using 2-level factorial design of experiments. Gunaraj and Murugan [9] have used 5-level factorial experiments to determine the main and interaction effects of process control variables on important bead geometrical parameters including bead volume quantitatively and optimal bead volume with maximum penetration, minimum reinforcement and bead width have been obtained successfully.

Of late, Taguchi techniques are used extensively for solving optimization problems in the field of production engineering [10].

This method utilizes a well balanced experimental design consisting of a limited number of experimental runs, called orthogonal array (OA) and signal-to-noise ratio (S/N) which serve as the objective function to be optimized within the experimental limits. Further, to determine the significance of factors on the responses, analysis of variance (ANOVA) has been used.

This paper presents the details of an experimental work on IS 2062 steel using SAW process to yield desired quality of bead , in terms of beads geometry, as influenced by voltage (V), current(A), welding speed (Tr) and nozzleto-plate distance (NPD) which are varied at five different levels. Greybased Taguchi approach has been carried out to solve this multiresponse optimization problem [11].

II. TAGUCHI METHOD

It is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost [5]. Taguchi method can be efficiently used for designing a system that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of strategically designed experiments. Taguchi approach to design of experiments is easy to adopt and apply; hence it has gained wide popularity in the engineering and scientific community [6-7]. The desired welding parameters are determined based on experience and the standard practice as follows [8].

Steps of Taguchi method are appended below:

1. Identification of the main function, to be optimized its side effects and failure mode.
2. Identification of noise factors, testing conditions and quality characteristics.
3. Identification the control factors and their levels.
4. Selection of orthogonal array and matrix experiment.
5. Conducting the matrix experiment.
6. Analyzing the data and prediction of the optimum level.
7. Determining the contribution of the parameters on the performance.
8. Performing the verification experiment and planning the future action.

III. LITRATURE REVIEW

Raveendra and Parmar [14] have built mathematical models using the fractional factorial technique to predict the weld bead geometry and shape relations (penetration, width, reinforcement height, width to penetration ratio and percentage dilution). The base metal was low carbon structural steel plate. The parameters of the Flux Cored Arc Welding process considered in his work were: arc voltage, welding current, welding speed, gun angle and nozzle-to-plate distance. They have developed models which can be used either to predict the bead geometry or to determine a combination or a range of parameters to obtain the desired bead geometry dimensions within the factors domain. Furthermore, these models can also be used in a production system for automatic control of welding conditions.

Yang, et al. [15] have used linear regression equations for computing the weld features (melting rates, total fusion area, penetration, deposit area, bead height and bead width) for SAW process variables (electrode extensions range, welding voltage, welding current, welding speed and electrode diameter) using both positive and negative electrode polarity. The base material used was a 19 mm thick ASTM A36 steel plate. They managed to develop regression equations for each weld feature in both polarity conditions. Their results indicated that the linear regression equations were equally useful for computing the various features of the SAW process.

Dhas and Kumanan[16] used NNPSO (Neural network model trained with Particle swarm optimization) to predict the weld quality of submerged arc welding with traditional algorithm which increase productivity, flexibility, safety. Also they suggested hardware control setup for online weld quality monitoring. Khan and Pandey investigated the effect of current on tensile strength and Nugget diameter of spot welds made on AISI-1008 steel sheets using Taguchi Method, Survey of literature indicates that no systematic work has been reported on the optimization of weld bead geometrical parameters for bead-on- plate SAS deposited on IS2062 steel using Taguchi Method. This steel is used in the fabrication of structures in Indian Raileays. This work, therefore, becomes important.

IV. METHOD OF EXPERIMENT

A. Selection of Material

Selection of material depends upon the desire weldability qualities which must rely on basic properties of the material, such as strength, corrosion or erosion resistance, ductility, and toughness. The properties of the various metallurgical characteristics associated with the thermal cycles encountered in the welding operation must also be included in the design process

a) Experimental setup:

The experiment was conducted at Research Design and Standards Organisation (RDSO) Lucknow with the following experimental set up:

The equipment used: The submerged arc welding equipment.
Welding rod used: W-1, 3.2 mm diameter.
Work Piece: IS: 2062 Steel plates of 300*150*20 mm size
Type of joint: Bead on plate
Flux: F-1
Electrode to work angle: 90o

b) Chemical composition of IS: 2062

C 0.23%; Mn: 1.50 5; S: .050%; P: 0.050%; Si: 0.40%; C.E: 0.42%
(Remaining iron)

c) Chemical composition of bare wire:

IRS class: 1
Grade of wire: W-1
C: 0.10%; Mn: 0.4-0.6%; Si: 0.03%; S: 0.03%; P: 0.03%; Cu: 0.4% the weight of copper includes copper coating also.

B. Analysis of S/N Ratio Based on Taguchi Method Taguchi recommends analyzing data using the S/N ratio that will offer two advantages; it provides guidance for selection the optimum level based on least variation around on the average value, which closest to target, and also it offers objective comparison of two sets of experimental data with respect to deviation of the average from the target. The experimental results are analyzed to investigate the main effects.

According to Taguchi method, S/N ratio is the ratio of "Signal" representing desirable value, i.e. mean of output characteristics and the "noise" representing the undesirable value i.e., squared deviation of the output characteristics. It is denoted by η and the unit is dB. The S/N ratio is used to measure quality characteristic and it is also used to measure significant welding parameters.

According to quality engineering the characteristics are classified as Higher the best (HB) and lower the best (LB). HB includes penetration which desires higher values. Similarly LB includes Heat Affected Zone (HAZ) width for which lower value is preferred.

The summary statistics the S/N ratio η (dB) is given by:

$$\eta = -10\ log\frac{1}{N}\sum_{i=1}^{n}\frac{1}{y^2}$$

Larger the best performance

$$\eta = -10\ log\frac{1}{N}\sum_{i=1}^{n}y^2$$

Lower the best performance

TABLE 1 Process parameters with their values at five levels

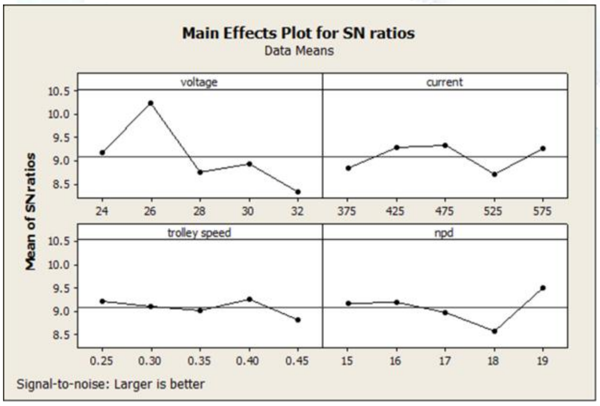
parameter	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Arc voltage (volts)	24	26	28	30	32
Welding current(amp.)	375	425	475	525	575
Trolley speed (m/min.)	0.25	0.30	0.35	0.40	0.45
Nozzle to plate distance(mm)	15	16	17	18	19

TABLE 2: Design matrix showing levels of factors

SL No	V	I	Tr	NPD
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

voltage	current	trolley speed	npd	penetration	S/N ratio
24	375	0.25	15	2.8	8.9432
24	425	0.30	16	2.9	9.2480
24	475	0.35	17	3.1	9.8272
24	525	0.40	18	2.6	8.2995
24	575	0.45	19	3.0	9.5424
26	375	0.30	17	3.1	9.8272
26	425	0.35	18	3.2	10.1030
26	475	0.40	19	3.4	10.6296
26	525	0.45	15	3.2	10.1030
26	575	0.25	16	3.4	10.6296
28	375	0.35	19	2.7	8.6273
28	425	0.40	15	2.9	9.2480
28	475	0.45	16	2.8	8.9432
28	525	0.25	17	2.6	8.2995
28	575	0.30	18	2.7	8.6273
30	375	0.40	16	3.0	9.5424
30	425	0.45	17	2.6	8.2995
30	475	0.25	18	2.7	8.6273
30	525	0.30	19	2.9	9.2480
30	575	0.35	15	2.8	8.9432
32	375	0.45	18	2.3	7.2346
32	425	0.25	19	3.0	9.5424
32	475	0.30	15	2.7	8.6273
32	525	0.35	16	2.4	7.6042
32	575	0.40	17	2.7	8.6273



Where C is current P is pressure and T is time.

Figure.9 Main Effect Plot For S/N Ratio

TABLE 3 Response table for S/N ratio for T-S strength

TABLE 3 Experimental Data and S/N ratio TABLE 4 Response table for S/N rati

level	voltage	current	trolley speed	npd
1	9.172	8.835	9.208	9.173
2	10.258	9.288	9.116	9.193
3	8.749	9.331	9.021	8.976
4	8.932	8.711	9.269	8.578
5	8.327	9.274	8.825	9.518
DELTA	1.931	0.620	0.445	0.940
RANK	1	3	4	2

C. *Analysis of Variance (Anova)*

ANOVA is a statistically based, objective decision-making tool for detecting any differences in the average performance of groups of items tested. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels.

TABLE-5 Analysis of Variance for SN ratios

Source	DF	SS	MS	F-ratio	P-value	C %
V (Volts)	4	10.4760	2.6190	10.14	0.003	60.8 %
Wf (Cm/s)	4	1.6997	0.4249	1.65	0.254	9.86%
Tr (Cm/s)	4	0.6102	0.1526	0.59	0.679	3.54%
NPD (Cm)	4	2.3773	0.5943	2.30	0.147	13.8%
Residual Error	8	2.0658	0.2582			
Total	24	17.2290				

R-Sq = 95.3% R-Sq(adj) = 81.1%;Significant at 95% confidence

V. CONCLUSION

The following conclusions could be drawn from the above investigation:

1. The response of S/N ratio with respect to Penetration indicates the welding voltage to be the most significant parameter that controls the weld penetration where's the other are comparatively less significant in this regard.
2. The contribution of voltage current trolley speed and nozzle to plate distance is 60.8%, 9.86%, 3.54% and 13.8%

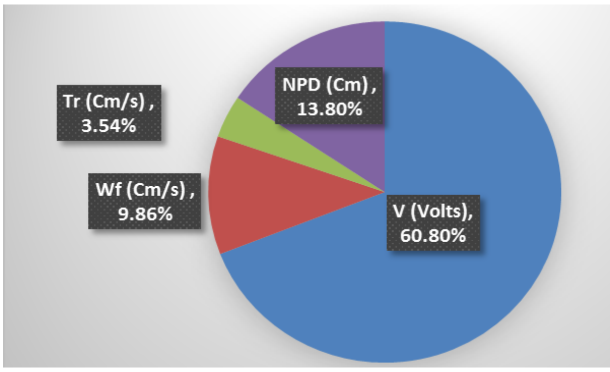


Fig. Contribution of parameters n submerged arc welding

3. Optimum results have been obtained by using Taguchi method at a voltage of 26V, current of 475A, trolley speed of 0.25m/min and NPD of 16mm.

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