Effect of Flux Cored Arc Welding Process Parameters on Weld Bead Geometry

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Abstract— Flux Cored Arc (FCA) welding process parameters are the most important factors which affecting the properties of the weld bead. This paper models the influence of welding parameters like welding voltage, welding speed, wire feed rate, standoff distance on bead geometry. The filler material used in this work was super duplex stainless steel of grade 2507. Set of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array and Taguchi signal to noise ratio (S-N Ratio) was employed to investigate the welding characteristics of super duplex stainless steel material and optimize the welding parameters. The success of FCA welding process in terms of providing weld ability good quality and high strength depends on the process conditions used in the setup. This research aims to identifying the main factors that have significant effect on weld bead geometry.

Index Terms— FCA welding, Super Duplex stainless steel (SDSS):2507, Process Parameter optimization, Taguchi L9, Orthogonal array, S-N Ratio, bead geometry, cladding.

1 Introduction

Flux Cored Arc welding process is a potential candidate for weld surfacing because of smooth weld bead; also it can be automated welding method with shielding gas. There are two types of techniques used in this welding process. One is with shielding gas another one is without shielding gas. The variants of FCAW process is self shielded and externally shielded. The response can be selected from dilution, reinforcement and bead width. Sensitivity analysis used to identify and rank important process variable, so deposited layer properties able to match the requirements of the process industries [1]. Bead geometry and dilution are strongly influenced by the heat input and welding current. For every welding process its parameters plays a very important role, especially heat input make a significant changes 0on the bead geometry. Experiment results shows that welding current increases then penetration, bead width and reinforcement also increases, if welding speed, NTPD and electrode angle affects penetration, width and reinforcement. However, Dilution increases with the increase in current, speed and open circuit voltage and decreases with increase in NTPD and electrode angle. This effect on weld bead geometry can't be neglected [2]. Several welding techniques used in the process industries depend upon their applications. Process manufacturing is very easy for their initial innovative ideas and investment. But maintenance and repair the processes have the dynamic problem in the process industries [3]. Corrosion is a dynamic problem, now most of the process industries used to recondition the components by using cladding [4]. Stainless steel is widely used in the cladding to improve the performance of the particular equipments. It is used to avoid corrosion on the cladded surface. Recent developments in the stainless steels make important material against corrosion. It is used to impart corrosion resistance properties both base plate and bead surface [5]. Super Duplex Stainless Steel has equal amount of ferrite and austenite content. SDSS 2507 has high chrmium content and nickel content to improve corrosion resistance properties of the bead surface and base plate [6]. Mild steel possess highly desirable properties like low cost, strength and ease of fabrication but it lacks corrosion resistance. The use of weld surfacing techniques imparts corrosion resistance to the substrate [7]. The corrosion resistance properties are dependent on the dilution of the filler materials in stainless steel cladding. Cladding is a process of depositing stainless steel layer on the carbon steel components to improve corrosion resistance [8]. Taguchi method is used to optimize the parameters and it should be ranked by their contribution on mechanical properties and bead geometry. It is very ease to operate and lower cost also time. Taguchi L9 is the simple optimized technique but the result was not accurate [9].

Advantages and applications:

- FCAW might be an "all-position" process with the right filler metals (the consumable electrode)
- No shielding gas required with some wires making it suitable for outdoor welding and windy conditions
- A high-deposition rate process (speed at which the filler metal is applied)
- Some "high-speed" (e.g., automotive) applications
- As compared to Shielding Metal Arc Welding and Gas Tungsten Arc Welding, there is less skill required for operators
- Metallurgical advantage from the flux such as the weld metal being confined initially from external factors until the slag is chipped away (10).

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2. EXPERIMENTAL PROCEDURE

2.1. FCAW carrying out parameters

Parameters are plays a very important vital role in this welding process. Welding voltage (24, 26, 28 v) is the primary criteria for the FCAW process. Wire feed rate (5715, 6350, 6985 mm/min) with electrode diameter 1.2mm SDSS 2507. Manipulator helps the base plate movement horizontally as well as vertically with the welding speed parameter (140, 160, 180 mm/min). Standoff distance (17, 19, 21 mm) is also the welding parameter; it is helping the bead geometry.

- Welding voltage
- Wire feed rate
- Welding speed
- Standoff distance.

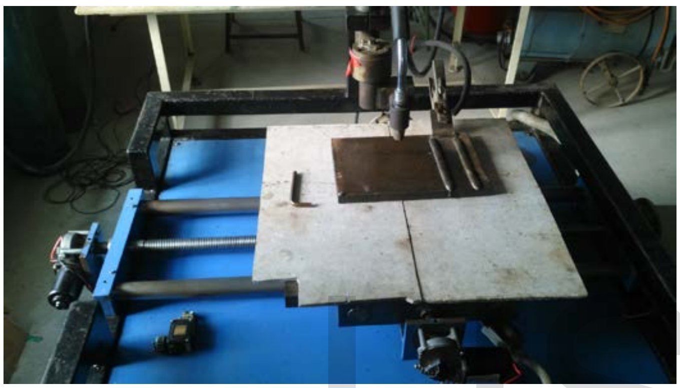

Fig.2.1. Experimental setup

2.2 Fixed variables

Fixed variables are very important thing on FCAW process. Below shown the fixed variables are to get required bead geometry. The inter pass temperature was maintained at 150°C with the help of infrared thermometer. Gas flow rate is maintained at 25 lit/min and this combination is reduced the spatter content on the process.

- Percentage overlap – 30%
- Inter-pass temperature - 150°C
- Shielding gas type and flow rate – 80%Ar – 20% CO_2

These variables are important for the welding process.

2.3. Heat input

Heat input is considered as very important factor because it affects bead geometry as well as further responses like dilution, microstructure and microstructure of the welding process.

Heat input= (60*V*I)/1000*S (KJ/mm)

V- Welding Voltage (V),

I- Welding Current (Amp),

S- Welding Speed (mm/min).

2.4 Work Material

The base material used for present work is low carbon structural steel IS: 2062:2011(Grade C), the dimensions of the work piece are 20mm thickness and its length and breadth are 300*130 mm. Cladding material is Super Duplex Stainless Steel SDSS: 2507. The electrode diameter is 1.2mm.

2.5. Taguchi's design method

Taguchi method is the basic key step to optimize the process parameters with high quality and without increasing cost. Quality uniqueness can be improved through these optimized parameters and the optimal process parameters obtained from the Taguchi method are insensitive to the difference of environmental circumstances and additional noise factors. Basically the design process parameters are complex to use. A number of process parameters increases while the large number of experiments has to be carried out. To resolve this task, the Taguchi method uses a special propose of orthogonal arrays to study the complete process parameter space with a small number of experiments only. The value of the loss function is further transformed into signal-to-noise (S/N) ratio.

2.5.1. SIGNAL-TO-NOISE[S-N] RATIO

Signal-to-Noise[S-N] ratios of ordinary attention for optimization

(I) Larger-The-Better: n = -10 Log10 [mean of sum squares of reciprocal of measured data]

2.6. ORTHOGONAL ARRAY EXPERIMENT

In the current work, 3-level and 4-factor development parameters that are welding voltage, wire feed rate, welding speed and standoff distance are considered. The values of such welding process parameters and its levels variables are listed in Table 2. The interface outcome between the parameters is not measured. The entire degrees of freedom of the entire process parameters are eight. The degrees of freedom of the orthogonal array be required to be larger than or at slightest equivalent to the degrees of freedom of whole welding process parameters. Hence, below shown the Taguchi L9 table derived from Minitab software.

TABLE.2.1: L9-3 level Taguchi orthogonal array

DESIGN MATRIX			
a	b	c	d
1	1	1	1
1	2	2	2
1	3	3	3
2	1	2	3
2	2	3	1
2	3	1	2
3	1	3	2
3	2	1	3
3	3	2	1

TABLE 2.2: Welding parameters and levels

Symbol	Welding Parameters	Unit	Level 1	Level 2	Level 3
a	Welding Voltage	volt	24	26	28
b	Wire Feed Rate	mm/min	140	160	180
c	Welding Speed	mm/min	5715	6350	6985
d	Nozzle To Plate Distance	mm	17	19	21

3 EXPERIMENTAL RESULT

According to the design matrix above combination experimental runs is done and the bead width as the responses. It is tabulated regards the combination of the input parameters. Below shown the table bead width results according to the combinations, further average bead width taken from every experimental runs. From over all twenty bead width has taken as reading by using digital vernier gauge and the average value calculated.

TABLE 2.3: Average bead width and bead height

WV	WFR	WS	NTPD	BW	BH
24	5715	140	17	25.69	25.84
24	6350	160	19	29.48	25.96
24	6985	180	21	24.56	25.92
26	5715	160	21	25.8	26.32
26	6350	180	17	21.61	26.28
26	6985	140	19	22.91	25.6
28	5715	180	19	21.49	26.36
28	6350	140	21	26.99	26.56
28	6985	160	17	21.24	25.96

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Fig.3.1. Polished specimens

4 RESULT

TAGUCHI ANALYSIS: BEAD WIDTH VERSUS WV,WFR, WS, NTPD

LINEAR MODEL ANALYSIS: SN RATIOS VERSUS WV, WFR, WS, NTPD

Estimated Model Coefficients for SN ratios

Term	Coef
Constant	27.7031
WV 24	0.7603
WV 26	-0.3278
WFR 5715	-0.0123
WFR 6350	0.5328
WS 140	0.3035
WS 160	0.3522
NTPD 17	-0.5593
NTPD 19	0.0421

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS
WV	2	2.61787	2.61787	1.30894
WFR	2	1.66447	1.66447	0.83224
WS	2	1.93817	1.93817	0.96908
NTPD	2	1.74632	1.74632	0.87316
Residual Error	0	*	*	*
Total	8	7.96683		

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TABLE.3.1:Response Table for Signal to Noise Ratios
Larger is better

Level	WV	WFR	WS	NTPD
1	28.46	27.69	28.01	27.14
2	27.38	28.24	28.06	27.75
3	27.27	27.18	27.05	28.22
Delta	1.19	1.05	1.01	1.08
Rank	1	3	4	2

EQUATIONS TAGUCHI ANALYSIS: BEAD HEIGHT VERSUS WV, WFR, WS, NTPD

LINEAR MODEL ANALYSIS: SN RATIOS VERSUS WV, WFR, WS, NTPD

Estimated Model Coefficients for SN ratios

Term	Coef
Constant	28.3286
WV 24	-0.0604
WV 26	-0.0076
WFR 5715	0.0282
WFR 6350	0.0591
WS 140	-0.0302
WS 160	-0.0026
NTPD 17	-0.0204
NTPD 19	-0.0386

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS
WV	2	0.024952	0.024952	0.012476
WFR	2	0.035793	0.035793	0.017897
WS	2	0.005978	0.005978	0.002989
NTPD	2	0.016204	0.016204	0.008102
Residual Error	0	*	*	*
Total	8	0.082927		

TABLE.3.2:Response Table for Signal to Noise Ratios
Larger is better

Level	WV	WFR	WS	NTPD
1	28.27	28.36	28.30	28.31
2	28.32	28.39	28.33	28.29
3	28.40	28.24	28.36	28.39
Delta	0.13	0.15	0.06	0.10

Rank	2	1	4	3

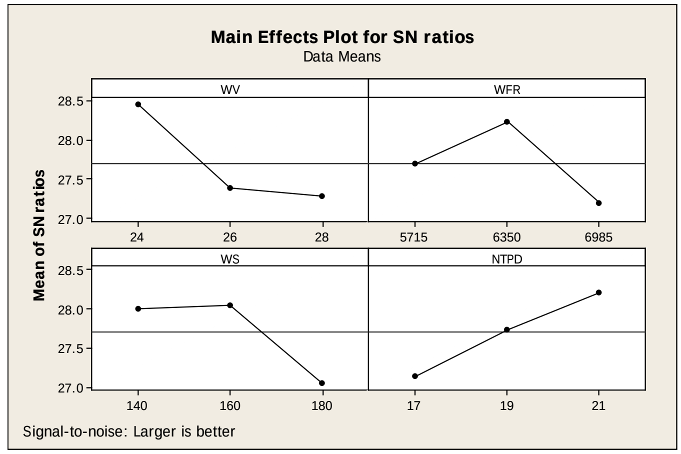

Fig.3.1. Graph for signal to noise(s-n) ratio for bead width

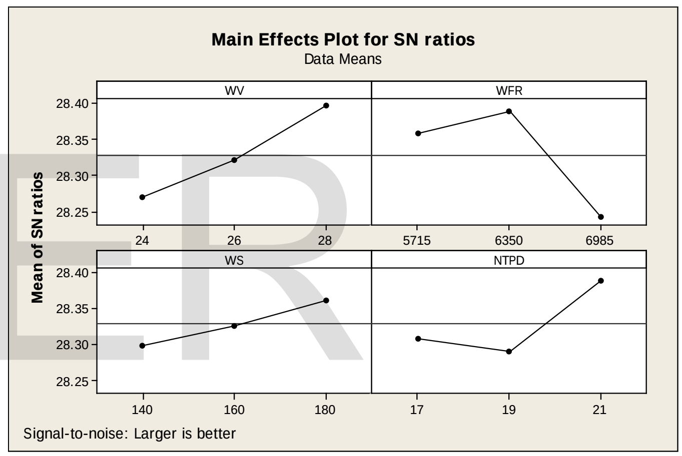

Fig.3.2. Graph for signal to noise(s-n) ratio for bead height

4. CONCLUSION

The separate input parameters belongs their contribution both bead width is.

- Welding voltage has contributed significantly to the bead width so it ranked first. It is give 27% contribution.
- Wire feed rate contributed 24% on bead width is the third ranked position on bead width.
- Welding speed parameter contributes 23% on bead width. So it is the fourth ranked position to the response.
- Nozzle to Plate Distance is the second ranked position and it is contributing 26% on bead width.

Parameter contribution for Bead Height.

- Wire Feed Rate is the first ranked position on bead height. It contributed 34%.
- Welding voltage is the second ranked position and it give 29 % contribution.
- 23% contributed on bead height by Nozzle to Plate

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Distance, so it third ranked position.

- But Welding speed is very least contribution on bead height. It contributes 14% on bead height.

But in design matrix ninth combination (WV-28v, WFR- 6985 mm/min, WS-160 mm/min, and NTPD-17 mm.) was boiled when experimental run conducted.

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