IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 6 Ver. IV (Nov. - Dec. 2015), PP 18-21
www.iosrjournals.org

Optimization of Weld Bead Geometry in Submerged Arc Welds Deposited On En24 Steel Alloy Using Taguchi Method

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Abstract: *Submerged arc welding (SAW) process is an important component in many industrial operations. The research on controlling metal transfer modes in SAW process is essential to high quality welding procedures. The experimentation work details the application of Taguchi techniques for optimization of weld bead geometry on EN24(low steel alloy)using submerged arc welding (SAW).The planned experiment work conducted in the semi automatic submerged arc welding machine and signal to noise ratio has been computed.*

The contribution of each factor has been calculated by Analysis of Variance (ANOVA) method. The result of the present experiment shows that the welding voltage is the highly dominating factor and most significant parameter that controls the bead penetration as compared to the other parameters.

Keywords: *submerged arc welding, Taguchi method, ANOVA, EN-24, EN-8, Current, Voltage, Travel speed.*

I. Introduction

Welding is an efficient, economical method for joining of metals. The advantages of welding, as a joining process, include high joint efficiency, good set up, flexibility and low fabrication costs. Due to its good reliability, deep penetration, smooth finish and high productivity, submerged arc welding (SAW) has become a natural choice in industries for fabrication. It is widely recognized as very productive welding process from single wire approach to more productive variants as twin wire, tandem ad metal power addition. EN24 is a high quality, high tensile, alloy steel and combines high tensile strength, shock resistance, good ductility and resistance to wear. EN24 is most suitable for the manufacture of parts such as heavy-duty axles and shafts, gears, bolts and studs. EN24 is capable of retaining good impact values at low temperatures. En24 steel is a difficult-to-machine material because of its high hardness, low specific heat and tendency to get strain hardened. The life of the cutting tool is shortened due to the tendency of the work material to carry the carbide particles with the outgoing chip at elevated temperature.En24 steel finds its typical applications in the manufacturing of automobile and machine tool parts. Because of its wide application En24 steel has been selected as the work material in this work.

b) Chemical composition of EN 24ALLOY:

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	V %	Mo %
0.3795	0.5717	0.04650	0.04961	0.2357	0.1104	1.26	1.066	0.0198	0.2177

II. Taguchi Method:

Taguchi method 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. Optimization of process parameters is the key step in Taguchi method to achieving high quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and optimal process parameters obtained from Taguchi method are insensitive to the variation of environmental conditions and other noise factors. Classical process parameters design is complex and not an easy task. To solve this task the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only.

III. Method Of Experiment

A.Selection Of Material

Selection of material depends upon the desire weld ability 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 Maharishi Markandeshwar University Mullana with the following experimental set up the equipment used was submerged arc welding equipment (TORNADO M-800) having electrode Cu wire, 3.2 mm diameter. The Work Piece used EN24 ALLOY STEEL of 400*80*20 mm size. Flux used for the SAW welding EN8 with Electrode to work angle 90^0. Parameters used for the experiment were voltage, welding current and travel speed as shown in the table3.1

TABLE 3.1 Process parameters with their values at three levels.

Parameter	**Level 1**	**Level 2**	**Level 3**	**Output parameter**
Arc Voltage(volts)	30	35	40	Weld penetration shape factor
Welding Current (amp.)	300	400	500	
Travel speed(m/hr)	20	25	30	

Taguchi method was used for the experiment with design of experiment **L_9 orthogonal array.** Table 3.2 shows the DOE L-9 orthogonal array.

TABLE3.2 Actual values of process parameters.

S. No.	**Design of Experiment (L_9 orthogonal array)**		
	Voltage(volts)	**Current (amp.)**	**Travel speed (m/hr.)**
1	30	300	20
2	30	400	25
3	30	500	30
4	35	300	25
5	35	400	30
6	35	500	20
7	40	300	30
8	40	400	20
9	40	500	25

IV. Result And Discussion:

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.

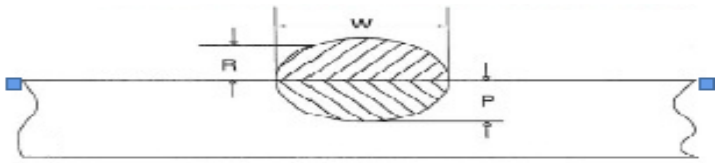


Figure 4.1: Cross section of ideal weld bead

The above figure 4.1 is the schematic representation of the bead on plate from Submerged Arc Welding. In this figure [P] represents the PENETRATION, [R] represents the REINFORCEMENT and [W] represents the WIDTH of the bead.

TABLE 4.1 Experimental data and S/N ratio.

Voltage	Current	Travel speed	P	R	W	WPSF	SNRA1	MEAN1
30	300	20	3.0	3	17	5.66667	15.0666	5.66667
30	400	25	4.8	3	21	4.37500	12.8196	4.37500
30	500	30	4.0	3	21	5.25000	14.4032	5.25000
35	300	25	5.0	3	20	4.00000	12.0412	4.00000
35	400	30	6.0	2	24	4.00000	12.0412	4.00000
35	500	20	6.0	2	23	3.83333	11.6715	3.83333
40	300	30	4.8	3	19	3.95833	11.9502	3.95833
40	400	20	9.0	2	33	3.66667	11.2854	3.66667
40	500	25	8.8	2	30	3.40909	10.6528	3.40909

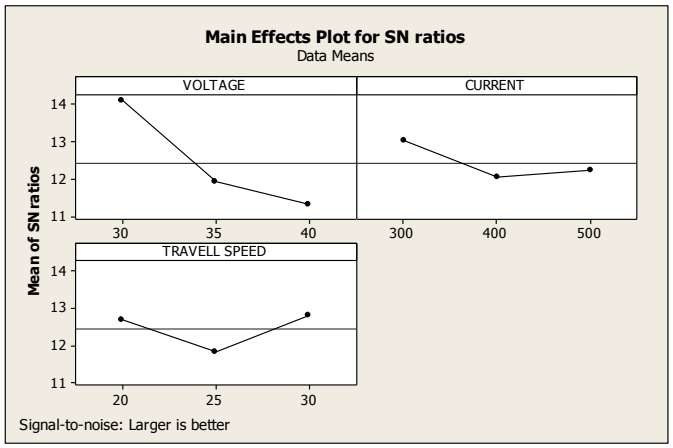
TABLE 4.2 Response Table for Signal to Noise Ratio.
LARGER IS BETTER.

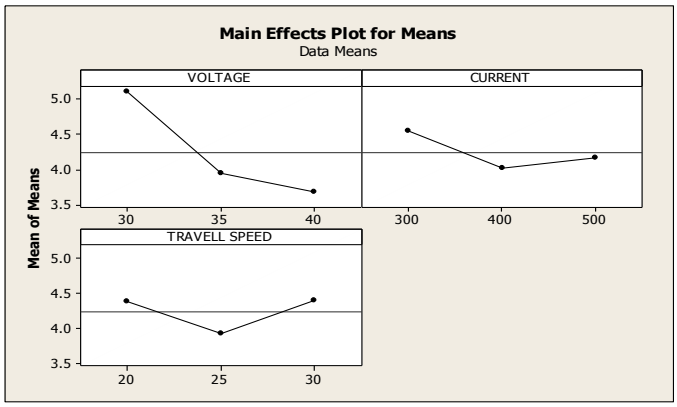
LEVEL	VOLTAGE	CURRENT	TRAVELL SPEED
1	14.10	13.02	12.67
2	11.92	12.05	11.84
3	11.30	12.24	12.80
Delta	2.80	0.97	0.96
Rank	1	2	3

TABLE 4.3 Response Table for Means.

LEVEL	VOLTAGE	CURRENT	TRAVELL SPEED
1	5.097	4.542	4.389
2	3.944	4.014	3.928
3	3.678	4.164	4.403
Delta	1.419	0.528	0.475
Rank	1	2	3

Above tables shows that the voltage is the most predominant factor having rank 1 other factors current and travel speed rank second and third respectively





Larger is better was selected for analysis of the Taguchi's design. It was observed that the optimum condition for the weld penetration shape factor A1, B1, C3

Analysis of Variance (ANOVA)

ANOVA table for WPSF is given in table 4.4 ANOVA table indicates the significance value of various input factors. If the p value given in the first column of ANOVA table is less than 0.05, this means the factor corresponding to that value of p is significant. In present study the p value for voltage is 0.028 coming lesser than 0.05. F value given in ANOVA table also indicates the significance of factors, higher the F value higher is the significance of that factor. Hence from table 4.4, voltage is the most significance factor.

TABLE 4.4 Analysis of Variance for SNRA1.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
VOLTAGE	2	12.9739	12.9739	6.4870	34.33	0.028
CURRENT	2	1.5831	1.5831	0.7915	4.19	0.193
TRAVELL SPEED	2	1.6376	1.6376	0.8188	4.33	0.188
Error	2	0.3779	0.3779	0.1890		
Total	8	16.5726				

S=0.434700 R-Sq=97.72% R-Sq=90.88%

V. Conclusion

- The results shows penetration will be at maximum value when welding arc voltage and welding current are at their maximum possible value and welding speed is at its minimum value.
- Arc voltage is main factor influence the Weld penetration shape factor (WPSF). It increases with arc voltage and current and decreases, with welding speed.
- Optimal parameters setting for larger depth is, current = 300 amp, voltage = 30 V, Speed= 30 m/hr.

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