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Effect of Saw Parameters on Chromium & Vanadium Elements Transfer in SS-202

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Abstract

The aim of the present work was to study the effect of welding current, arc voltage, and weld speed on Chromium and Vanadium element transfer and to optimize the process following suitable Taguchi experimental design. Beads on plate weld were deposited on SS-202 at different welding parameter combinations. During analysis of Chromium Welding voltage and current were found to be the most significant factors leading to changes in chromium element transfer. During analysis of Vanadium Welding speed and current were found to be the most significant factors leading to changes in vanadium element transfer. The results revealed that welding voltage has an appreciable influence on weld composition of Chromium element and welding speed has an appreciable influence on weld composition of vanadium element. Data investigated in this paper can be used to specify welding variables for desired Chromium and Vanadium composition.

Keywords: *Submerged arc welding, chemical composition, Taguchi design of experiment, S/N ratio, Experimental Design*

Nomenclature

SAW:	Submerged Arc Welding
SN:	Signal to Noise
ANNOVA:	Analysis of Variance
WS:	Welding Speed
DCEP:	Direct current Electrode Positive
DCEN:	Direct Current Electrode Negative
AC:	Alternating Current
DC:	Direct Current
CV:	Constant Voltage
GA:	Genetic algorithm
PSO:	Particle Swarm Optimization

1. Introduction

Welding as it is generally understood today is comparatively a new comer amongst the fabrication processes though smith forging to join metal pieces was practiced even before Christ. Though there are a number of well-established welding processes but arc welding with coated electrodes is still the most popular welding process over the world. Arc welding in its present form appeared on the industrial scene in 1880's. Arc welding, however, was not accepted for fabrication of critical components till about 1920 by which time coatings for electrodes had been well developed. Submerged Arc Welding is a fusion welding process in which heat is produced from an arc between the work and a continuously fed filler metal electrode. The molten weld pool is protected from the surrounding atmosphere by thick blanket of molten flux and slag formed from the granular fluxing material pre-placed on the work.

1.2 Control Parameters

The control factors and their values were chosen on the basis of a pilot experiment by varying one factor at a time. Based on the pilot study, current, voltage, welding speed, was identified as the control factors. The levels of the possible contributing factors were decided using the following methodology

1.2.1 Welding Current

When we increase the welding current the pressure exerted by the arc increases which drives out the molten metal from beneath the arc and that lead to increased depth of penetration. The width of weld remains almost unaffected. As the increased welding current is accompanied by increase in wire feed rate, it results in greater weld reinforcement. Variation in current density has nearly the same effect on weld geometry as the variation in magnitude of current. Welding with DCEP produces deeper penetration than DCEN. For a given welding current, a decrease of wire diameter results in increase in current density. This results in a weld with deeper penetration but of somewhat reduced width. The submerged arc welding process usually employs wires of 2 to 5mm diameter, thus for deeper penetration at low currents a wire of diameter 2 to 3mm is best suited.

1.2.2 Arc-Voltage

Arc voltage varies in direct proportion to the arc length. With the increase in arc length the arc voltage increases and thus more heat is available to melt the metal and the flux. However, increased arc length means more spread of arc column, this leads to increase in weld width and volume of reinforcement while the depth of penetration decreases. The arc voltage varies with welding current and wire diameter, and in SAW it usually ranges between 30 to 50 volts.

1.2.3 Weld Speed

With increase in welding speed, the width of weld decreases. However, if the increase in speed is small the depth of penetration increases because the layer of molten metal is reduced which leads to higher heat conduction towards the bottom of the plate. With further increase in welding speed, above 40 m/hour, the heat input per unit length of the weld decreases considerably and the depth of penetration is thus reduced. At speed above 80 m/hour, lack of fusion may result. It has been established experimentally that as a first approximation the welding speed, S, for a well-shaped weld should be based on the following relationship.

$S = 2500/I_n$ m/hour

Where I_n is the welding current in amperes (Pandey*et al*, 1994)

2. Materials and Methods

2.1 Materials

In this study SS-202 was used having dimensions 100x62x9 mm. The samples were cut from SS-202 flat and were machined to get the desired dimensions. The chemical composition of the material is shown in table 1.

Table 1 Chemical composition of SS-202

Material	%age by weight
C	0.115
Mn	8.946
P	0.02646
S	0.01946
Si	0.6461
Cu	0.1103
Ni	4.756
Cr	18.2
V	0.0645

Fig.1 Specimen

2.2. Design of experiments

Table 2 L-16 Array

Expt. No.	V	I	WS
	(V)	(A)	(m/hr)
1	26	210	24
2	26	240	26
3	26	270	28
4	26	300	30
5	28	210	26
6	28	240	24
7	28	270	30
8	28	300	28
9	30	210	28
10	30	240	30
11	30	270	24
12	30	300	26
13	32	210	30
14	32	240	28
15	32	270	26
16	32	300	24

2.2.1 Selection of welding parameters

Table 3 Values of parameters

Welding Parameters	Units	Symbol	Levels			
Current	A	A	210	240	270	300
Voltage	V	V	26	28	30	32
Weld Speed	m/hr	WS	24	26	28	30

Using the trial experiments the various values given in table 2 were taken to build the L-16 array using Minitab software. The experiments were performed according to the L-16 array shown in 2.2.

Fig.2 welded specimens

3. Results and discussion

3.1 Responses

Table 4 Responses as per Taguchi array

Expt. No.	V (V)	I (A)	WS (m/hr)	Cr (%)	V (%)
1	26	210	24	4.796	0.0266
2	26	240	26	7.138	0.035
3	26	270	28	5.352	0.0883
4	26	300	30	9.081	0.0883
5	28	210	26	7.736	0.0313
6	28	240	24	2.422	0.0221
7	28	270	30	6.07	0.0309
8	28	300	28	7.244	0.0324
9	30	210	28	8.985	0.0305
10	30	240	30	9.755	0.0347
11	30	270	24	7.415	0.0312
12	30	300	26	8.828	0.0456
13	32	210	30	8.522	0.0416
14	32	240	28	9.132	0.1146
15	32	270	26	9.022	0.0293
16	32	300	24	9.163	0.0889

Table 5 S/N ratio

Expt. No.	V (V)	I (A)	WS (m/hr)	Cr S/N ratio	V S/N ratio
1	26	210	24	13.61758	-31.5024
2	26	240	26	17.07153	-29.1186
3	26	270	28	14.57032	-21.0808
4	26	300	30	19.16267	-21.0808
5	28	210	26	17.77033	-30.0891
6	28	240	24	7.683483	-33.1122
7	28	270	30	15.66377	-30.2008
8	28	300	28	17.19957	-29.7891
9	30	210	28	19.07036	-30.314
10	30	240	30	19.78455	-29.1934
11	30	270	24	17.40222	-30.1169
12	30	300	26	18.91725	-26.8207
13	32	210	30	18.61083	-27.6181
14	32	240	28	19.21132	-18.8163
15	32	270	26	19.10606	-30.6626
16	32	300	24	19.24075	-21.022

3.2 Analysis of experimental data for Chromium

The Chromium (Cr) element along with the input process parameters is given in table 3. Minitab 17 software was used to analyze the measured response.

3.2.1 Effect of input factors on Cr

The response table for signal to noise ratio for Cr is shown in table 5 and the responses in table 4. For Cr, the calculation of S/N ratio follows Larger the Better model. Therefore, voltage (V) has the maximum effect on Manganese in the weld metal. The effect is shown in table 6.

Table 6: Response Table for Signal to Noise Ratios

Larger is better

Table 6

Level	V(Volt)	I(Amp)	WS(m/h)
1	16.11	17.27	14.49
2	14.58	15.94	18.22
3	18.79	16.69	17.51
4	19.04	18.63	18.31
Delta	4.46	2.69	3.82
Rank	1	3	2

Response **Table 7** for Means

Level	V(Volt)	I(Amp)	WS(m/hr)
1	6.592	7.510	5.949
2	5.868	7.112	8.181
3	8.746	6.965	7.678
4	8.960	8.579	8.357
Delta	3.092	1.614	2.408
Rank	1	3	2

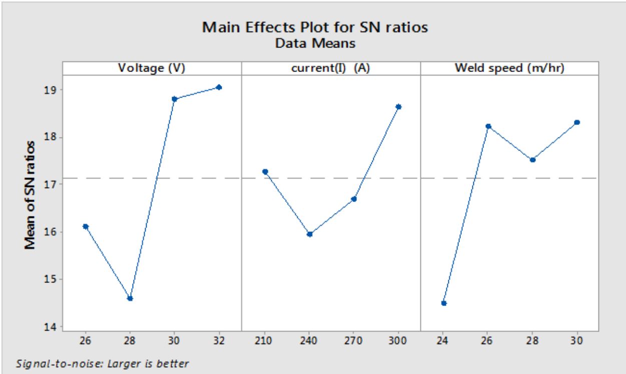

Table 8ANOVA Table for Signal to Noise ratio

Source	DF	Seq SS	Adj. SS	Adj. MS	F	P
Voltage	3	55.92	55.92	18.64	3.34	0.098
Current(I) A	3	15.55	15.55	5.184	0.93	0.483
Weld speed(m/hr)	3	38.8	38.8	12.932	2.31	0.176
Residual error	6	33.52	33.52	5.587		
Total	15	143.79				

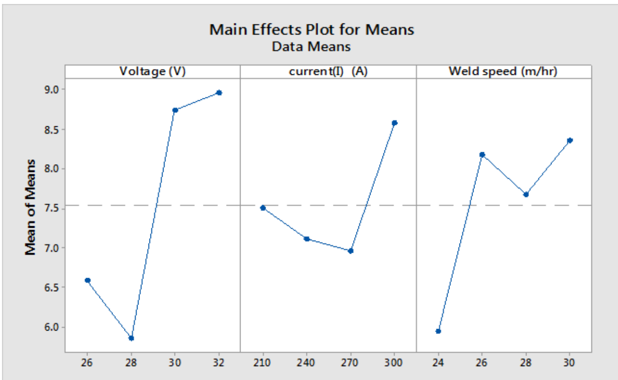

Table 9ANOVA Table for Means

Source	DF	Seq SS	Adj. SS	Adj. MS	F	P
Voltage	3	28.657	28.657	9.552	5.32	0.040
Current(I) A	3	6.379	6.379	2.126	1.18	0.392
Weld speed(m/hr)	3	14.515	14.515	4.838	2.69	0.139
Residual error	6	10.781	10.781	1.797		
Total	15	60.332				

3.2.4 Optimization of parameters

Optimal Parameters of Input Factors

Table 10

Physical	**Optimal Combination**		
Requirement	V(Volt)	I(Amp)	WS(m/hr)
Maximum Cr	32	300	30
	Level-4	Level-4	Level-4

It can be seen from the graphs that for Cr to be maximum, all the factors have to be at high level 4.

3.3 Analysis of experimental data for Vanadium

The Vanadium (V) element along with the input process parameters is given in table 3. Minitab 17 software was used to analyze the measured response.

3.3.1 Effect of input factors on V

The response table for signal to noise ratio for V is shown in table 5 and the responses in table 3. For Cr, the calculation of S/N ratio follows Larger the Better model. Therefore, voltage (Volts) has the maximum effect on Manganese in the weld metal. The effect is shown in table 11.

Table 11 Response Table for Signal to Noise Ratios Larger is better

Level	V(Volt)	I(Amp)	WS(m/h)
1	-25.70	-29.88	-28.94
2	-30.80	-27.56	-29.17
3	-29.11	-28.02	-25.00
4	-24.53	-24.68	-27.02
Delta	6.27	5.20	4.17
Rank	1	2	3

Table 12 Response Table for Means

Level	V(Volt)	I(Amp)	WS(m/hr)
1	0.05955	0.03250	0.04220
2	0.02918	0.05160	0.03530
3	0.03550	0.04493	0.06645
4	0.06860	0.06380	0.04888
Delta	0.03942	0.03130	0.03115
Rank	1	2	3

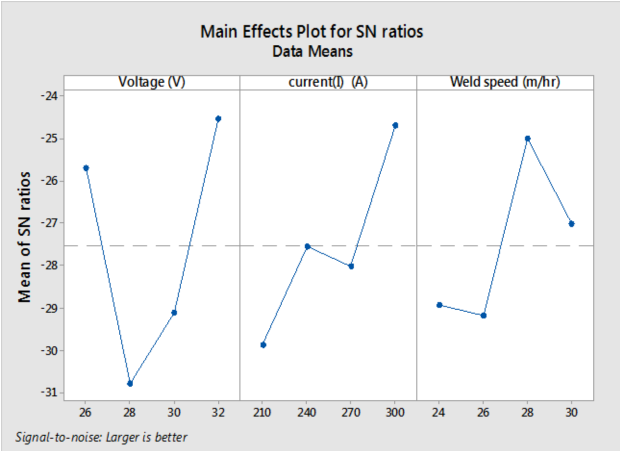

Table 13ANOVA Table for Signal to Noise ratio

Source	DF	Seq SS	Adj. SS	Adj. MS	F	P
Voltage	3	55.92	55.92	18.64	3.34	0.098
Current(I) A	3	15.55	15.55	5.184	0.93	0.483
Weld speed(m/hr)	3	38.8	38.8	12.932	2.31	0.176
Residual error	6	33.52	33.52	5.587		
Total	15	143.79				

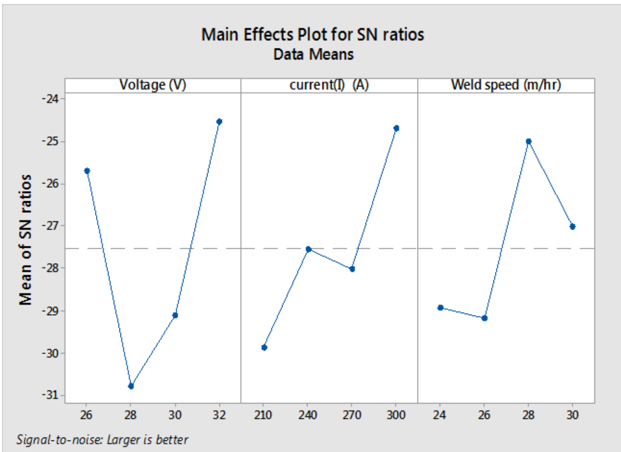

Table 14 ANOVA Table for Means

Source	DF	Seq SS	Adj. SS	Adj. MS	F	P
Voltage	3	0.004273	0.004273	0.001424	2.05	0.208
Current(I) A	3	0.002049	0.002049	0.000683	0.98	0.461
Weld speed(m/hr)	3	0.002144	0.002144	0.000715	1.03	0.444
Residual error	6	0.004165	0.004165	0.000694		
Total	15	0.012630				

3.2.4 Optimization of parameters

Table 15 Optimal Parameters of Input Factors

Physical	**Optimal Combination**		
Requirement	V(Volt)	I(Amp)	WS(m/hr)
Maximum V	32	300	28
	Level-4	Level-4	Level-3

It can be seen from the graphs that for V to be maximum, voltage and current have to be at high level 4. Weld speed should be at level 3

Conclusion for Chromium

The combined effect of welding parameters on weld metal Cr in SAW process was examined. Accordingly, the following conclusions can be drawn:

- For controlling the Chromium metal transfer, all the factors are equally important.

Conclusion for Vanadium

The combined effect of welding parameters on weld metal V in SAW process was examined. Accordingly, the following conclusions can be drawn:

- For controlling the Vanadium metal transfer, Voltage was found to be the most significant factor.

Scope for future work

In this present study only metal for Chromium and Vanadium transfer have been studied. Keeping the view of future scope, other elements transfer like carbon, sulphur, phosphorous etc. can be studied. Also, the other parameters like electrode extension, electrode polarity, and different fluxes can be added.

Acknowledgements

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