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Research Article

Investigating the Effect of Saw Parameters on Manganese Element Transfer in SS-201

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Abstract

In industries and research organizations most broadly used welding methods are shield metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and submerged arc welding (SAW). The SAW process is often preferred because it offers high production rate, high melting efficiency, ease of automation and low operator skill requirement. The purposed work is to evaluate the effect of SAW parameters for chemical analysis of weld bead. In this work the experimentation is done to analyze that which factor is most contributing towards the various element transfers in weld bead and also find the percentage of contribution of each variable factor. The aim of the present work was to study the effect of welding current, arc voltage, and weld speed on Manganese and element transfer and to optimize the process following suitable Taguchi experimental design. Beads on plate weld were deposited on SS-201 at different welding parameter combinations. During analysis of Manganese Welding current and voltage were found to be the most significant factors leading to changes in manganese element transfer. The results revealed that welding current has an appreciable influence on weld composition of Manganese element. Data investigated in this paper can be used to specify welding variables for desired manganese 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

1. Introduction

The Submerged arc welding is a process in which the joining of metals is produced by heating with an arc or arcs between a metal electrode or electrodes and the work. This is a single-wire welding system first used in the mid-1930s. The first patent on submerged arc welding process was taken out in 1935 and covered an electric arc beneath a bed of granulated flux. Developed by E O Paton Electric Welding Institute, Kiev, during the Second World War.

The SAW process is often preferred, because it offers high production speed, high efficiency and simplicity with low operator skill requirement. Operational variables used in the SAW process results in changing heat supply in the weldments, as a consequence there is a deterioration of the chemical constituents of weld bead. Therefore, the properties of the metal could not sufficiently match the weldments in order to ensure good performance in service, especially in low temperature service. The arc is initiated and maintained between the end of bare wire electrode and the work. As the electrode melts, that is fed into the arc by set of rollers, propelled by a directed motor. Wire feed speed is controlled automatically to match the frequency with which the electrode melts, thus the arc length remains constant (like MIG/MAG-constant voltage). Arc is working under a layer of granular flux, hence submerged arc. Some of the flux melts and provide a protective blanket cover over the molten weld pool. The residual flux remains unaffected and can be recovered and re-used, recycled, only if it is dry and uncontaminated. In Semi-automatic version the welding gun is controlled by the operator, a hopper is mounted over the welding gun and carries a small amount of flux.

2. Literature

R. A. Farrar *et al.* [1982] have studied Properties and microstructure of Stress-relieved submerged-arc weld metal containing niobium. They have used Post-weld heat-treatment (PWHT) normally adopted for welded

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fabrications, when the thickness of the plate exceeds 25 mm. The study was mainly focused on minimizing the residual stresses, which can contribute to buckling and brittle failure. From the study; finally it was concluded that:

1) The main effects of PWHT of niobium-bearing steel weldments are Nb (CN) precipitation and dislocation recovery and ordering. Carbide spheroidization and precipitation has also been observed.
2) Post-weld heat-treatment (PWHT) is absolutely advantageous up to a 0.025 wt.% niobium content in the weld metal. Beyond this level, the increase of yield point causes a slow but sure drop in toughness.

N.D. Pandey *et al*. [1993] the aim of their work is to evaluate the Effect of submerged arc welding parameters and fluxes on element transfer behaviour and weld-metal chemistry. The material has been used mild steel plates with dimensions of 80 x 250 x 20 mm, using the five fluxes and electrode wire with a diameter of 4 mm. From this study they concluded that:-

1) Submerged arc welding current and voltage influence the weld-metal composition and the element transfer behaviour for the elements, viz manganese, silicon, carbon and Sulphur.
2) For the management of the weld composition of the metal, welding voltage is more effective than the welding current.

R.S. Chandel *et al*. [1998] have studied the Effect of metal powder addition on mechanical properties of submerged arc welds. The experimental material was a 25 mm thick mild steel plate with low carbon and having measurement 350×220×25 mm. They have concluded that with the accumulation of powder impact properties became superior but there is an adequate amount of evidence to say that the weld metal is stronger and tougher than the base metal.

N. Murugan et al. [2005] through their study on prediction and control of weld bead geometry and shape relationships in submerged arc welding of pipes. They concluded that arc voltage should be less significant negative influence on the penetration and reinforcement, but also have a positive impact on the bead width, penetration size factor and firming shape factor of penetration factor.

Abhay Sharma *et al*. [2006] have studied on practical approach towards mathematical modeling of deposition rate during twin wire SAW. They concluded that

1) Deposition can be mathematically modeled by welding parameters and involved the loss of the metal can be traced.
2) The close proximity, lead and trail wires act in union and both the wire have the same behavior during melting.

Saurav Datta et al. [2007] have studied Slag recycling in submerged arc welding & its influence on weld quality leading to parametric optimization. The experiment was conducted on mild steel plate of 100x40x10mm using L25 array. They concluded that 20% of the slag-mix can be consumed, in order to obtain the optimal bead, without any negative impact on the geometry of the bead.

Saurav Datta et al. [2008] have used application of taguchi philosophy for parametric optimization of bead geometry and HAZ width in submerged arc welding using mixture of fresh flux and fused flux. The experiment was conducted on mild steel plate of 100x40x12mm using L9 orthogonal array. From this they concluded that:

1) 10% of the slag mixture can be used for obtaining the optimal width of the bead and the depth of the HAZ.
2) 15 to 20% slag mix for reinforcement and depth of penetration.

Hari Om *et al*. [2012] have studied on mathematical modeling of heat affected zone in SAW process using factorial design technique. They concluded that:

1) The width of the HAZ effectively varies according to the speed of wire feed voltage with no load at all levels under electrode in adverse conditions.
2) The effect of process variables on HAZ area, similar to that of the HAZ Width.
3) The negative Electrode polarity produces smaller HAZ under all conditions, in General, with the exception of the high wire feed percentage.

Mohit Sharma *et al*. [2014] have studied on Application of Taguchi Method to Study the Effect of Saw Parameters on Nickel Element Transfer. They concluded that:

1) Welding Current is the most significant factor for transfer of nickel element to the Weld metal.
2) It is also concluded that, with the increase in the value of the arc voltage and the welding speed nickel element has a decreasing form.
3) Arc voltage is least important factor for transfer of nickel constituent to weld metal.

Nayab Singh *et al*. [2015] have studied the Effect of Saw Parameters on Slag Content of Weld Metal. The test material was SS 310 plates of dimensions 110mm x 55mm x8mm. They concluded that:-

1) The welding voltage is the main factor for production of slag contents during the welding.
2) It also concluded that with increase in the current and welding speed slag content shows rising form.
3) Speed of the welding is least significant factor for production of slag contents during the welding.

Degala Venkata Kiran *et al*. [2015] have studied on the Arc interaction and molten pool behavior in the three wire submerged arc welding process. The test material was HSLA steel plate of 1000 mm×300 mm×25.4 mm dimension. They concluded that:

1) Front electrode is connected to a direct current electrode positive polarity, the middle and the end of the electrode on the alternating current with a trapezoidal waveform, penetration of the weld is produced mainly in the middle and the end arcs and the related impact of droplets.
2) The center of the arc of the displacement and its effect on the release of droplets having a significant impact on the molten metal stream and the resulting shape of the weld pool in the three wires SAW process.

3. Materials and Methods

3.1 Materials

In this study SS-201 was used having dimensions 100x60x10 mm. The samples were cut from SS-201 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-201

Material	%age by weight
C	0.10
Mn	5.90
P	0.020
S	0.017
Si	0.26
Cu	0.12
Ni	3.88
Cr	16.82

3.2. Design of experiments

Sr. No.	I(Amp)	V(Volt)	WS(m/h)
	A	B	C
1	250	28	29
2	250	30	31
3	250	32	33
4	250	34	35
5	275	28	31
6	275	30	29
7	275	32	35
8	275	34	33
9	300	28	33
10	300	30	35
11	300	32	29
12	300	34	31
13	325	28	35
14	325	30	33
15	325	32	31
16	325	34	29

3.3 Selection of welding parameters

Table 2 Values of parameters

Sr. No.	Factors (Units)	Symbols	levels			
1	Current (Amp)	I	250	275	300	325
2	Voltage (Volt)	V	28	30	32	34
3	Welding speed (m/h)	WS	29	31	33	35

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.

4. Results and discussion

4.1 Responses

Table 3 Responses as per Taguchi array

Expt. No.	V	I	WS	Mn
	(V)	(A)	(m/hr)	(%)
1	28	250	29	3.5760
2	28	275	31	3.9730
3	28	300	33	4.8110
4	28	325	35	4.4950
5	30	250	31	4.4700
6	30	275	29	4.0870
7	30	300	35	6.3050
8	30	325	33	5.2440
9	32	250	33	3.3670
10	32	275	35	3.7580
11	32	300	29	5.4450
12	32	325	31	4.4280
13	34	250	35	3.3650
14	34	275	33	4.0420
15	34	300	31	4.7930
16	34	325	29	4.5000

Table 4 S/N ratio

Expt. No.	V	I	WS	Mn
	(V)	(A)	(m/hr)	S/N ratio
1	28	250	29	-11.0680
2	28	275	31	-11.9824
3	28	300	33	-13.6447
4	28	325	35	-13.0546
5	30	250	31	-13.0062
6	30	275	29	-12.2281
7	30	300	35	-15.9937
8	30	325	33	-14.3933
9	32	250	33	-10.5449
10	32	275	35	-11.4991
11	32	300	29	-14.7200
12	32	325	31	-12.9242
13	34	250	35	-10.5397
14	34	275	33	-12.1319
15	34	300	31	-13.6121
16	34	325	29	-13.0643

Table 5 Response Table for Signal to Noise Ratios Larger is better

Level	V(Volt)	I(Amp)	WS(m/h)
1	12.44	11.29	12.77
2	13.91	11.96	12.88
3	12.42	14.49	12.68
4	12.34	13.36	12.77
Delta	1.57	3.2	0.2
Rank	2	1	3

Table 6 Response Table for Means

Level	V(Volt)	I(Amp)	WS(m/hr)
1	4.214	3.695	4.402
2	5.026	3.965	4.416
3	4.25	5.338	4.366
4	4.175	4.667	4.481
Delta	0.851	1.644	0.115
Rank	2	1	3

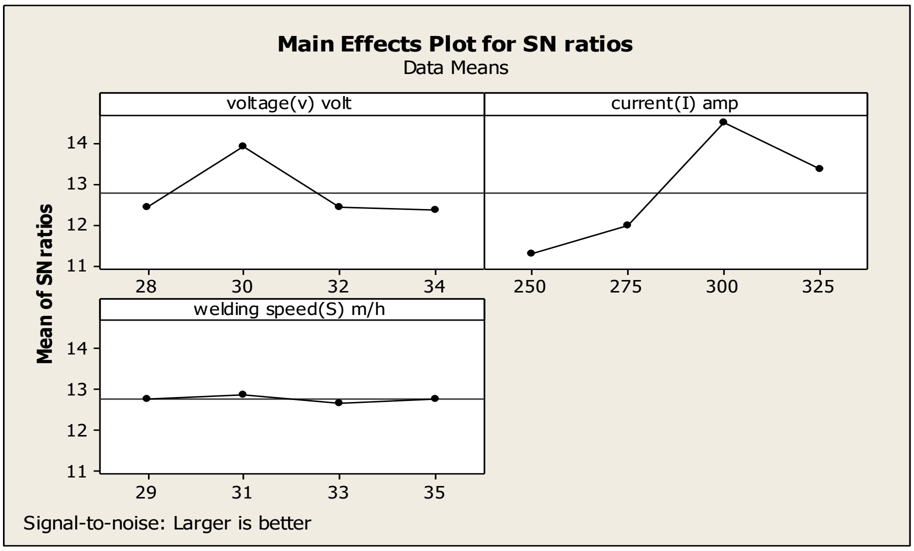
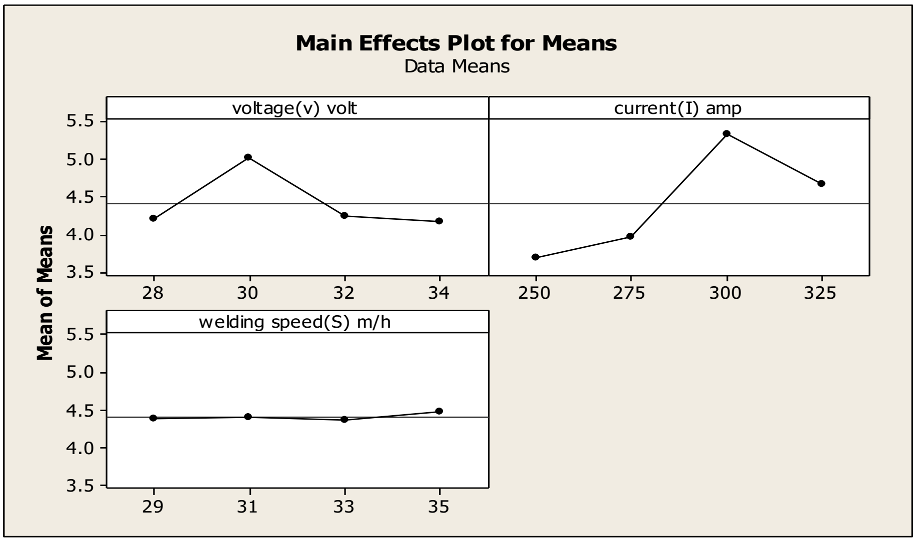


Table 7ANOVA Table for Signal to Noise ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
V(Volt)	3	6.8319	6.8319	2.27730	4.97	0.046	19.91
I(Amp)	3	24.6448	24.6448	8.21493	17.92	0.002	71.83
WS(m/h)	3	0.0824	0.0824	0.02745	0.06	0.979	0.24
Residual Error	6	2.7502	2.7502	0.025794			8.01
Total	15	34.3092					

Table 8 ANOVA Table for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
V(Volt)	3	1.99767	1.99767	0.66589	4.76	0.050	21.21
I(Amp)	3	6.55138	6.55138	2.18379	15.62	0.003	69.58
WS(m/h)	3	0.02755	0.02755	0.00918	0.07	0.967	0.29
Residual Error	6	0.83858	0.83858	0.13976			8.90
Total	15	9.41519					



4.2 Analysis of experimental data

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

4.2.1 Effect of input factors on Mn

The response table for signal to noise ratio for Mn is shown in table 4 and the responses in table 3. For Mn, the calculation of S/N ratio follows Larger the Better model. Therefore, current (V) has the maximum effect on Manganese in the weld metal. The effect is shown in table 5.

4.2.2 Optimization of parameters

Table 9 Optimal Parameters of Input Factors

Physical	Optimal Combination		
Requirements	I(Amp)	V(Volt)	WS(m/h)
Maximum Mn	300	30	31
	Level-3	Level-2	Level-2

It can be seen from the graphs that for Mn to be maximum, factor V (V) has to be at level 2, current (A) has to be at high level 3 & weld speed has to be at high level 2.

Conclusion

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

- For controlling the manganese metal transfer, welding current is more effective than the welding voltage and welding speed.

Scope for future work

In this present study only Manganese metal transfer has 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.

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