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To Study the Effect of SAW Parameters on Manganese Element Transfer Using Taguchi Technique

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Abstract

In industries and research organizations most widely used welding methods are shield metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and submerged arc welding (SAW.) In this work the effect of of various parameters on Manganese element transfer was studied. L9 Orthogonal array was used & three factors Current,Voltage,Welding Speed were taken. It is concluded that current is the most significant factor for the transfer of manganese element to the weld metal. It is also concluded that with an increase in the value of voltage & welding speed manganese element shows a decreasing trend.

Keywords: Submerged arc welding, Manganese, Taguchi design of experiment, S/N ratio

1. Introduction

In industries and research organizations most widely 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. It was first used in industries in the mid 1930's as a single-wire welding system (Parmar, 1992). The operating variables used in the SAW process results in varying heat input in the weldment The consequence of this is the deterioration of the chemical constituents of the weld bead. Therefore, the properties of the parent metal cannot adequately match those of the weldment to ensure good performance in service, especially in low temperature services. The control parameters are (i) Welding current (ii) Arc Voltage (iii) Weld speed.(Mohit Sharma el at, 2014). The experimentation is done to find out which factor contribute towards the increase in percentage of manganese. Manganese increases hardenability and tensile strength of steel, but to a lesser extent than carbon. It is also able to decrease the critical cooling rate during hardening, thus increasing the steels hardenability much more efficient than any other alloying elements. Manganese is capable to form Manganese Sulphide (MnS) with sulphur, which is beneficial to machining. At the same time, it counters the brittleness from sulphur and is beneficial to the surface finish of carbon steel.(Lawrence el at, 1980)

For welding purposes, the ratio of manganese to sulphur should be at least 10 to 1. Manganese content of less than 0.30% may promote internal porosity and cracking in the weld bead, cracking can also result if the content is over 0.80%. Steel with low Manganese Sulphide ratio may contain sulphur in the form of iron Sulphide (FeS), which can cause cracking (a "hot-short" condition) in the weld.(Lawrence el at, 1980)

2. Literature Survey

Pandey *et al* (1994) showed in their work that welding current and voltage have an appreciable influence on element transfer, as well as on weld composition. Weldment properties such as strength, toughness and solidification cracking behaviour are affected by chemical composition of the weld. Chandel *et al* (1997) through their research paper presented theoretical predictions of the effect of current, electrode polarity, electrode diameter and electrode extension on the melting rate, bead height, bead width and weld penetration, in submerged-arc welding. Khallaf *et al* (1997) described cracking behaviour during the submerged arc welding of medium carbon steel plates and found that the cracking susceptibility increases with an increase in the welding current and decreases with an increase in the welding speed or the electrode wire feed rate. It also increases with increases in the plate rolling reduction ratio and with decrease in the plate thickness. Gunaraj & Murugan (1999a) studied the effect of controllable process variables on the heat input and the area of the heat-affected zone (HAZ) for bead-on-plate and bead-on joint welding using mathematical models developed for the submerged arc welding of pipes. A comparative study of the area of the heat-effected zone between bead-on-plate and bead-on-joint welding was then carried out. Gunaraj & Murugan (1999b), Murugan & Gunaraj (2005) again addressed the main problem faced in the manufacture of pipes by the SAW process regarding the selection of the optimum combination of input variables for achieving the required qualities of weld. They suggested the solution by the development of mathematical models through effective and strategic planning and the execution of experiments by RSM. Tušek (2000) worked on mathematical modelling of melting rate in twin-wire welding for the first time and found his models were very accurate practically. A multi wire SAW process was modelled by Wen *et al* (2001) using a general purpose finite element package for thick wall line pipes. It was shown that the geometric distortion and residual stresses and strains can be minimized through process optimization. Pandey (2004) proposed a relationship between welding current and direct SAW process parameters using two level half factorial design. Interactive effects of direct parameters were also studied. The study performed by Karaoˇglu & Seçgin (2008) focuses on the sensitivity analysis of parameters and fine tuning requirements of the parameters for optimum weld bead geometry. Changeable process parameters such as welding current, welding voltage and welding speed are used as design variables. Effects of all three design parameters on the bead width and bead height show that even small changes in these parameters play an important role in the quality of welding operation. The results also reveal that the penetration is almost non-sensitive to the variations in voltage and speed. Dhas & Kumanan (2011) used Taguchi's design of experiments and regression analysis to establish input–output relationships of the process. By this relationship, an attempt was made to minimize weld bead width, a good indicator of bead geometry, using optimization procedures based on the genetic algorithm (GA) and particle swarm optimization (PSO) algorithm to determine optimal weld parameters. Ghosh *et al* (2011a) addressed the issue associated with the uncertainties involved with the heat affected zone (HAZ) in and around the weldment produced by SAW process. The most intriguing issue is about HAZ softening that imparts some uncertainties in the welded quality. It increases the probability of fatigue failures at the weakest zones caused by the heating and cooling cycle of the weld zone. They assessed the heat affected zone of submerged arc welding of structural steel plates through the analysis of the grain structure by means of digital image processing techniques. It was concluded that the grains are predominantly of smaller variety and the counts for larger grain are almost negligible. The absence of larger size grains in the image vouch for the soundness of the weld in comparison to the competing welding methodologies of structural steel plates. Ghosh *et al* (2011b, c) used graphical technique to predict submerged arc welding yield parameters and studied the effect of main factors, viz. current, wire feed rate, travel speed and stick out and the interactions among the main factors on the welding bead parameters. The interactions depicted the level of confounded character of the main factors with respect to the significant yield parameters of the process. A series of measurements was carried out by Shen *et al* (2012) on specimens of submerged arc welded plates of ASTM A709 Grade 50 steel. The bead reinforcement, bead width, penetration depth, HAZ size, deposition area and penetration area increased with increasing heat input but the bead contact angle decreased with it. The electrode melting efficiency increased initially and then decreased with increasing heat input but the plate melting efficiency and percentage dilution changed only slightly with it. Cooling time exhibited a very good linear relationship with the total nugget area, heat transfer boundary length, and nugget parameter.

3. Taguchi's philosophy

Taguchi's philosophy is an efficient tool for the design of high quality manufacturing systems. Dr. Genichi Taguchi, a Japanese quality management consultant, has developed a method based on orthogonal array experiments, which provide much-reduced variance for the experiment with optimum setting of process control parameters. Thus the integration of design of experiments (DOE) with parametric optimization of process is achieved in the Taguchi method.

This will provide desired results. The desired results refer to the acceptable quality parameters of the product. For welded joint, this will mean desired mechanical properties of the joint, which-in turn-depend on bead geometry. Again, control of the process parameters will lead to optimal bead.

An orthogonal array (OA) provides a set of well balanced (minimum experimental runs) experiments and Taguchi's signal-to-noise ratios (S/N), which are logarithmic functions of desired output; serve as objective functions for optimization. This helps in data analysis and prediction of optimum results. The steps involved in the Taguchi method are as follows.(Antony et al, 2001):

Step 1 Formulation of the problem.

Step 2 Identification of control factors, noise factors and signal factors.

Step 3 Selection of factor levels, possible interactions and degrees of freedom associated with each factor and the interaction effects.

Step 4 Design of an appropriate orthogonal array

Step 5 Experimentation and data collection.

Step 6 Statistical analysis and interpretation of experimental results.

Step 7 Conducting confirmatory tests.

4. Experimental setup

The experiments were conducted on Submerged Arc Welding Machine, Model -Tornado Saw M-800 transformer and FD10-200T welding tractor available at MM University. The welding current, voltage and welding speed could be regulated, displayed and preset on the panel of the tractor for the convenience of the operator. Process parameters with their studied levels are shown in table 1.

The AISI SS 304 plates of 102mm x 64mm x12mm dimensions were welded, using taguchi's L_9 (3x3) orthogonal array. The objective of the study was to evaluate the effect of various process parameters in a SAW process on the weld bead geometry. The factors and their associated levels were chosen on the basis of a pilot experiment by varying one factor at a time.

Table 1. Factors with their levels

S. No.	Factors(Units)	Levels		
1	Current (A)	325	355	395
2	Voltage (V)	27	30	33
3	Welding speed(m/h)	18	24	28

The experimental design was completed using the Taguchi's Fractional Factorial Experiments (FFEs). In the present experimental situation, three factors were varied during the experiment. Three factors (namely current, welding speed and voltage) varied at three levels, have two degrees of freedom (dof) associated with them. A possible matrix for studying a combination of a two-level and three-level factors is an nine trial Orthogonal Array labeled as L9 matrix.(P.J. Ross, 1995) As shown in table 2.

Table 2. L_9 Orthogonal Array used for experimentation

Sr. No.	I(Amp)	V(Volt)	ws(m/h)
	A	B	C
1	325	27	18
2	325	30	24
3	325	33	28
4	355	27	24
5	355	30	28
6	355	33	18
7	395	27	28
8	395	30	18
9	395	33	24

5. Results and analysis

After the experimentation, the results were calculated with the help of using MINITAB software, and also the analysis of variance for s/n ratio as well as for the mean is calculated. The analysis of variance for means shown in table 3 below.

Table 3 Analysis of variance for means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
I(Amp)	2	0.003889	0.003889	0.001944	3.57	0.219
V(Volt)	2	0.002756	0.002756	0.001378	2.53	0.283
ws(m/h)	2	0.000156	0.000156	0.000078	0.14	0.875
Residual Error	2	0.001089	0.001089	0.000544		
Total	8	0.007889				

Further the response were calculated for s/n ratio as well as for means also. On the basis of these responses the rank were calculated for the desired result as shown in table 4 below.

Table 4 Response Table for Means

Level	I(Amp)	V(Volt)	ws(m/h)
1	1.257	1.267	1.257
2	1.273	1.260	1.25
3	1.223	1.227	1.247
Delta	0.050	0.040	0.010
Rank	1	2	3

It is being concluded from the above table that out of three parameters Current, Voltage & welding speed Current is the most significant factor for the transfer of manganese element to the weld metal.

The fig 1. Shows the main effect plots for means, from the graph plot it is clear that values of response will increase with increase in I(Amp). And Decreases with increase in V(Volt) and ws(m/h). Shown in figure 1.

Main Effects Plot for Means

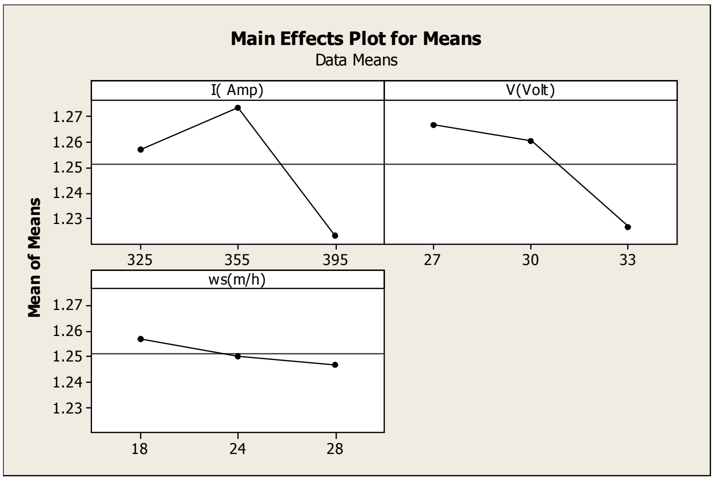

Figure. 1

6. Conclusions:

1. It is also concluded that with an increase in the value of voltage & welding speed manganese element shows a decreasing trend.

2. Current is the most significant factor for the transfer of manganese element to the weld metal.

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