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To Study the Effect of SAW Parameters on Chromium Element Transfer

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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 the beginning of D.O.E phase, pilot experiments were performed for preliminary study. The various parameters, their ranges and levels were selected based on results of the pilot study. Suitable Technique for orthogonal arrays was used for design of experiments after the pilot experiments. Based on the findings of the Pilot study, actual experimentation work was designed and input machining parameters and their values finalized. The results are expected to show that the response variables (output parameters) strongly influenced by the control factors (input parameters). So, the results which are obtained after experimentation analyzed and modeled for their application in manufacturing industry. In this work the effect of various parameters on chromium element transfer was studied. L16 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 chromium element to the weld metal.

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 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.

The experimentation is done to find out which factor contributes towards the increase in percentage of chromium. These elements are well known in the alloying of steel. Chromium stabilizes ferrite but slows down transformation rate. It also increases hardness and strength and has a greater influence when manganese is at low concentrations. With chromium additions, toughness falls as reported in studies of mechanical properties of high strength steel weld metals. It provides solid solution strengthening and promotes carbide formation. Chromium also increases hardenability and gives both oxidation and corrosion resistance. Chromium increase resistance to high temperature corrosion and are well known for giving resistance against creep in heat resistant steels.

2. Literature Survey

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*. [1996] have studied Effect of increasing deposition rate on the bead geometry of submerged arc welds. They analyzed the impact of current, electrode diameter, electrode polarity, and the electrode extension of the melting speed, height of bead, bead width and weld penetration, in submerged-arc welding. They concluded that:

1) The melting rate of SAW can be increased by four methods:
   (i) Using higher current.
   (ii) Using straight polarity.
   (iii) Using a reduced diameter electrode.
   (iv) Using an extended electrode extension.
2) The difference in the percentage of the speed of melting, height of bead, width of bead and bead penetration, is influenced by the level of current and polarity.
3) For a given heat input welds features such as the bead height, the width of the weld bead and bead penetration are affected in a different way and a different extent any of the above approaches are used to increase the speed of melting.

R.S. Chandel *et al*. [1997] with the help of their study showed the theoretical estimation 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.

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.

Gunaraj & Murugan (1999) 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.

Y.S. Tarng et al. [2000] have used Fuzzy Logic in the Taguchi Method for the Optimization of the Submerged Arc Welding Process. They have used L8 orthogonal array with five columns and eight rows. That array has seven degrees of freedom and it can handle two-level process parameters. 24 mm thick mild steel plate were used with dimensions 120 mm x 60 mm and they studied that the performance characteristics such as deposition rate, hardness and dilution can be improved by means of this approach (grey relation).

Y.S. Tarng *et al*. [2002] have used grey-based Taguchi methods to determine submerged arc welding process parameters in hardfacing. For Experimentation they deposited a martensitic stainless steel hardfacing layer on 30x80x120mm mild steel plate by SAW process. The use of grey relationship did an evaluation on the dilution speed, hardness and speed of the establishment, and finally made the analysis of variance. From this study came to the conclusion that the performance characteristics, such as harnesses, dilution and deposition rate improves together with grey relationship.

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:

1) 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.
2) Wire Feed had a significant positive impact, but the speed of welding had a significant negative impact on the most important parameters of the bead. Penetration has increased about 1.3 mm as wire feed rate was increased from −2 to +2 limit however penetration has decreased about 1mm as welding speed was increased from −2 to +2 limit.

P. Kanjilal *et al*. [2005] have studied on combined effect of flux and welding parameters on chemical composition and mechanical properties of submerged arc weld metal. 18 mm steel low-carbon plates have been used for experimentation. From the study; finally it was concluded that:

1) Welding speed influences weld metal carbon content through oxidation reaction; whereas, Sulphur and phosphorus content of weld metal are influenced by the dilution of weld deposit.
2) The transfer of nickel out of the flux in the weld, is found to be obstructed by oxides formed during slag–metal reaction.
3) Weld metal yield strength and hardness are intended above all welding parameters; whereas, the toughness of impact is determined by the flux of the mixture of variables.

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 studied the grey based taguchi method for optimization of bead geometry in submerged arc bead on plate welding. They have used L25 orthogonal array on the test material of mild steel plates of 100x40x10mm.with the grey relation and Analysis of variance they concluded that the area must be a minimum of HAZ in order to prevent changes in the microstructure. Speed is the most important factor, to minimize the area of the HAZ.

Abhay Sharma et al. [2009] have studied on Estimation of heat source model parameters for twin-wire submerged arc welding. The test material was a rectangular piece of mild steel with dimensions 300 x 200 x 25 mm. They concluded that:

1) Heat source model parameters for twin-wire welding are quite different from the single-wire heat source model. Due to mutual interaction between two wires, more melting and less penetration the previous heat source model parameters for single-wire welding requires that was adjusted for twin-wire welding.
2) Effect of flux consumption on the heat transfer pattern can be enumerated by applicable compensation in the heat source model.

Krishankant *et al*. [2010] have studied on Determination of Flux Consumption in submerged arc welding by the Effect of Welding Parameters by Using R.S.M Techniques. They concluded that:

1) RSM can be used effectively in analyzing the cause and the effect of process parameters on the response. RSM is also used to position graphs for different responses show the interaction of the influence of different process parameters.
2) Flux consumption increased with the increase in open circuit voltage and very minor Increases with increases in current.
3) Welding speed has negative effect on consumption of flux.
4) Consumption of flux also decreases in very small extent when there is increase in the nozzle to plate distance.

Ana Ma. Paniagua-Mercado *et al*. [2011] have studied on Chemical and Physical Properties of Fluxes for SAW of Low-Carbon Steels. They have come to the conclusion that the determination of the phase allows us to identify the different types of oxides and fluxes as radicals embroiled in sintering of raw materials. This quantification enables you to find out what the anions and the cations will be present in an electric arc. The most reactive responds quickly and can be either absorbed in a slag or kept in the weld as inclusions. This work shows the importance of choice for mixed flux, in order to improve the mechanical properties of steel welds.

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.

Brijpal Singh et al. [2013] they have done a review study on effect of flux composition on its behavior and bead geometry. With the help of their detailed examination has shown that the flux of the components has a major impact on the behavior of the flux and the geometry of the shape of the bead. Bearing capacity of the welded joint depends not only on the microstructure, but it is also affected by the physical behavior of the flux, and the geometry of bead. Among the main features that are affected by the flux ingredients are the arc stability, slag detachability, capillarity, viscosity and basicity index.

A. Sarkar et al. [2014] have studied on Optimization of Welding Parameters of Submerged Arc Welding Using Analytic Hierarchy Process (AHP) Based on Taguchi Technique. The experiment was conducted on plain carbon steel of dimensions 200 mm× 100 mm× 12 mm. They concluded that:

1) The results of the test gave a higher penetration, less the width of the bead and reinforcement.
2) The application of Taguchi methods in experimentation led to the identification of the optimal setting of the parameters of the reaction in the experimental domain through the concept of S/N ratio.
3) The effect of speed of wire feed to the overall geometry of the bead is more significant than other welding parameters.

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

1) Welding current is the most significant factor for maximum hardness during the welding.
2) It also concluded that with increase in arc voltage hardness shows growing form but with increase in welding speed hardness shows decreasing form.
3) Arc voltage is the least significant factor for maximum hardness during the welding.

Kahraman Sirin *et al*. [2016] have studied Influence of the chemical composition of weld electrode on the mechanical properties of submerged arc welded pipe. The test material was pipes 846-mm outer diameter and an 8.74-mm-thick wall and are made of an API-X65 steel strip. They concluded that the CVN toughness of weld metal improved by increasing the content of Mn in electrodes used. The presence of Ti in weld electrode improves the toughness and ductility with slight loss of CVN of tensile strength of welded metal by increasing the content of Ti.

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), that is 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:

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.

3. Experimental setup

The whole experiment was done on Submerged Arc Welding Machine, Model -Tornado Saw M-800 transformer and FD10-200T welding tractor available at MM University. The electrode is EH14. 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. The polarity is kept positive. The nozzle distance is kept constant i.e. 20 mm. Process parameters with their studied levels are shown in table 1.

The AISI SS 201 plates of dimensions 100mm x 60mm x 10mm were welded, using taguchi's L_{16} 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

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

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 four levels. A possible matrix for studying a combination of a four-level and three-level factors is a sixteen trial Orthogonal Array labeled as L16 matrix. As shown in table 2.

Table 2 L_{16}Orthogonal Array used for experimentation

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

4. Results and analysis

Table 3 Response table for SN ratio

Level	V(Volt)	I(Amp)	WS(m/h)
1	18.34	18.27	19.50
2	20.02	18.38	19.35
3	18.95	20.14	19.27
4	19.67	20.19	18.86
Delta	1.62	1.92	0.64
Rank	2	1	3

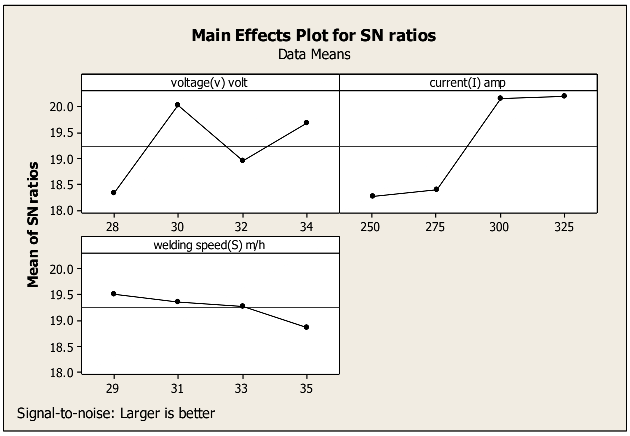

Fig.1 Main effects plot for SN ratios

Table 4 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
V(Volt)	3	6.7715	6.7715	2.2572	1.55	0.297	22.56
I(Amp)	3	13.5779	13.5779	4.5260	3.10	0.111	45.24
WS(m/h)	3	0.8985	0.8985	0.2995	0.21	0.889	2.99
Residual Error	6	8.7590	8.7590	1.4598			29.18
Total	15	30.0069					

Table 5 Response Table for Means

Level	V(Volt)	I(Amp)	WS(m/h)
1	8.304	8.276	9.527
2	10.105	8.357	9.431
3	8.969	10.216	9.346
4	9.748	10.276	8.821
Delta	1.800	2.000	0.707
Rank	2	1	3

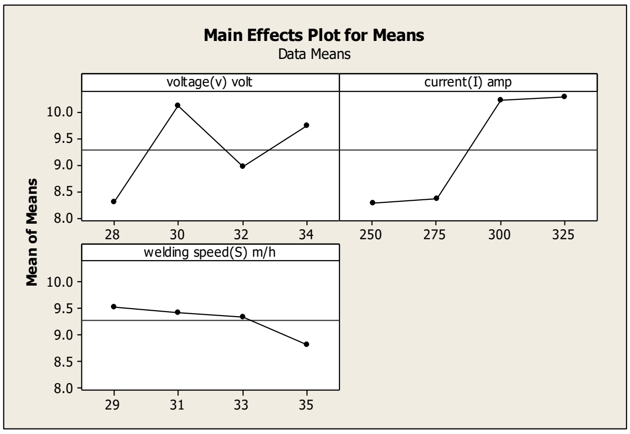

Fig.2 Main effects plot for Means

Table 6 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
V(Volt)	3	7.789	7.789	2.5964	1.65	0.275	23.36
I(Amp)	3	14.912	14.912	4.9707	3.16	0.107	44.73
WS(m/h)	3	1.198	1.198	0.3992	0.25	0.856	3.59
Residual Error	6	9.432	9.432	1.5719			28.29
Total	15	33.331					

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 chromium element to the weld metal.

Conclusions

It is concluded that for Cr be maximum factor I(Amp) has to be at high level 4, V(Volt) has to be at high level 2 & WS(m/h) has to be at high level 1. As shown in table below

Optimal combination for Chromium

Physical	Optimal Combination		
Requirements	I(Amp)	V(Volt)	WS(m/h)
Maximum Cr	325	30	29
	Level-4	Level-2	Level-1

According to ANOVA, the values of percentage of contribution of the process parameters are calculated for chromium. According to value of percentage of contribution of each variables the rank of variables in descending order are Current (1) > Voltage (2) > Welding speed (3).

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