

Effect of Process Parameter in SAW- A Review

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Abstract— In research organizations and industries, 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. This study expose the different works have been done in the past for improving different properties of welded material. This study also exhibits the effect of different welding process parameters that affect the weld chemistry. Depending upon the requirement the details of past work will we easily obtained for future work with the help of this study.

Keywords— *Welding Current, Arc Voltage, Welding Speed, Wire Diameter, Wire size.*

I. INTRODUCTION

In industries and research organizations, submerged arc welding (SAW) is one of the most widely used welding method, because it offers high production rate, high melting efficiency, ease of automation and low operator skill requirement, the SAW process is often preferred. 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.

II. CONTROL PARAMETERS

2.1. Welding Current: It controls the melting rate of the electrode and also control the weld deposition rate. It also controls the depth of penetration and thereby the extent of dilution of the weld metal by the base metal. Too high a current causes excessive weld reinforcement which is wasteful, and burn-through in the case of thinner plates or in badly fitted joints, which are not provided with proper backing.

2.2. Arc-Voltage: Arc voltage, also called welding voltage, means the electrical potential difference between the electrode wire tip and the surface of the molten weld puddle.

2.3. Welding speed : The welding speed also affects the penetration. If the speed is increased relative to the original value, penetration will be decreased and the weld will be narrower. Reducing the speed, increases penetration and results in a wider weld. However, reducing the welding speed to about 20–25 cm/min (depending on the actual value of the current) can have the opposite effect, i.e. a reduction in penetration, as the arc is prevented from transferring thermal energy to the parent metal by the excessive size of the weld pool. If the welding speed is to be changed while penetration is kept constant, it is necessary to compensate by adjustment of the welding current, i.e. to increase or decrease it.

2.4. Wire diameter: For a given current, current density can be changed by changing the wire size. Greater wire diameter results in a reduction in penetration and, to some extent, also the risk of burning through at the bottom of the weld. In addition, the arc will become more difficult to strike and arc stability will be adverse.

2.5 Wire sizes and types of current: Wire sizes normally used for butt welding are 2.0, 2.5 and 3.0 mm, with wire separations of about 8 mm. DC welding, with the wire positive relative to the work piece, is preferable, as this results in the best arc stability and least risk of porosity. When hard facing using tubular wires, it is generally preferable for the wire to be negative, resulting in minimum penetration and highest deposition rate. Commonly used tubular wire diameters are 2.4, 3.0 and 4.0 mm.

III. LITERATURE SURVEY

In this Paper, important research works related to present work have been reviewed. These works provide the background for defining the objective of our work i.e., to see the effect of input processing parameters on welding qualities, welding properties and internal defects. Findings from the papers studied are discussed below.

(V.Gunaraj and N. Murugan, 2000) They studied the various process control variables and weld bead quality parameters in SAW of pipes manufactured out of structural steel (IS: 2062). Mathematical models were developed for the submerged arc welding of 6- mm-thick structural steel plates using 3.15-mm-diameter steel electrodes. The models were developed using the five-level factorial technique to relate the important process-control variables — welding voltage, wire feed rate,

welding speed and nozzle-to-plate distance — to a few important bead-quality parameters — penetration, reinforcement, bead width, total volume of the weld bead and dilution. The models developed were checked for their adequacy with the F test. Using the models, the main and interaction effects of the process-control variables on important bead geometry parameters were determined quantitatively and presented graphically. The developed models and the graphs showed the direct and interaction effects of process variables on the bead geometry are very useful in selecting the process parameters to achieve the desired weld bead quality. Also, the precision of the results obtained with the mathematical models were tested by using conformity test runs.

(V.Gunaraj and N. Murugan, 2000) developed mathematical models to relate the process parameters and the weld bead quality parameters. Further, the optimization of weld bead volume was carried out using the optimization module available in the *MATLAB* version 4.2b software package. The mathematical models thus developed for optimization are also helpful in predicting the weld bead quality parameters and in setting process parameters at optimum values to achieve the desirable weld bead quality at a relatively low cost with a high degree of repeatability and increased production rate. Total volume of the weld bead, an important bead parameter, were optimized (minimized), keeping the dimensions of the other important bead parameters as constraints, to obtain sound and superior quality welded pipes. Sensitivity analysis was also carried out to predict the direct and few interaction effects of important bead parameters on the total volume of the weld bead, and the results are presented in graphical form. The results of the sensitivity analysis are very useful in understanding the interdependence of various weld bead quality parameters in controlling the volume of the weld bead, to improve weld quality, to increase productivity with the available welding facilities and to minimize the total welding cost.

Datta et al. (2002) investigated the weldability properties of 20 mm thick plates using the shielded metal arc welding (SMAW) process. The authors suggested that susceptibility of steel to cold cracking is related to the carbon equivalent (CE) and its position in the Graville diagram. High strength, quench and tempered plates having yield strength of 670 MPa (carbon equivalent, CE: ~0.6) are susceptible to a crack-sensitive microstructure and cold cracking during welding.

Rayes et al, (2004) predicted weld bead penetration as a function of welding process parameters. They optimized process parameters for maximizing weld penetration.

Murugan and Gunaraj (2005) suggested that mechanical strength of welds is influenced not only by the composition of the metal but also by the weld bead shape in SAW. So the selection of the process variables and control of weld bead shape has become essential. In the experimental work, bead on plate has been taken on plates (IS 2062 carbon steel of 6mm thickness) with 3.15 mm diameter wire. Prediction equations were developed for penetration, reinforcement, bead width, PSF and RFF in terms of weld parameters; voltage, speed, wire feed rate and nozzle to tip distance.

S. R. Bhide et. al.(2006) compares submerged arc welding (SAW), gas metal arc welding (GMAW), and friction stir welding (FSW) in terms of their buckling property by measuring the longitudinal residual stresses on HSLA-65 steel welded plates of identical dimensions. The blind hole drilling method was used to measure the longitudinal residual stress and distortion measurements were obtained by using digital gauges at 40 points on the plates. Analyses of the longitudinal residual stresses and distortion measurements revealed that the FS-welded plate has buckling distortion, while the GMAW and SAW plates have angular and bowing distortions.

P. Kanjilal, et. al.(2007) studied the transfer of elements across the molten weld pool by developing quadratic models in terms of flux ingredients with the application of statistical experiments for mixture design. Bead-on-plate weld deposits were made at fixed welding parameters using submerged arc welding fluxes prepared as per extreme vertices algorithm of mixture experiments in a CaO-MgO-CaF₂-Al₂O₃ flux system. The results show that some of the individual flux ingredients and their binary mixtures have a predominant effect on weld metal transfer of oxygen, manganese, silicon, and carbon contents. The analysis of experimental data also indicates that transfer of oxygen is affected by several properties of flux ingredients such as oxygen potential, thermodynamic stability, and viscosity. In the element transfer of silicon, both thermo chemical and electrochemical reaction mechanisms operate simultaneously. Transfer of manganese is principally related to the weld metal oxygen contents as well as electrochemical reaction in the molten weld pool. The transfer of carbon was generally governed by the oxidation reaction. Iso-response contour plots were also developed to quantify the transfer of elements against different flux compositions.

P. J. Konkol et.al.(2007) develop procedures, and demonstrate the feasibility of FSW 0.25-in.- (6-mm-) thick HSLA-65 steel weldments fabricated from 10-ft- (3-m-) long plate sections, on a production- size, purpose-

built FSW machine. Measurements were taken to compare the amount of weld distortion with that of a conventional submerged arc weldment. In addition, the mechanical properties and microstructures of the weld regions were evaluated to further compare the two welding processes. Both the friction stir and submerged arc weldments exhibited significant longitudinal weld distortion. The submerged arc weldment was bowed in the transverse direction, while the friction stir weldment exhibited no transverse distortion. The transverse weld tensile strengths of both weldments were acceptable, and the CVN toughness of the FSW stir zone was significantly higher than that of the submerged arc weld metal. There was little difference in heat-affected-zone toughness. This indicates that FSW is technically feasible for joining HSLA-65 steel for structural applications.

Kaaoglu and Secgin (2008) carried out the sensitivity analysis of SAW parameters; welding current, welding voltage and welding speed for optimum weld bead geometry. The weld bead width, height and penetration were selected as design variables. A mathematical model was constructed using multiple curvilinear regression analysis. The study revealed that the penetration is almost non-sensitive to the variations in voltage and speed.

Datta et al. (2008) optimized bead geometry (bead width, reinforcement, depth of penetration and depth of HAZ) using grey relational analysis. Taguchi's L25 orthogonal array (OA) was used in the work for design of experiment and experiments were conducted to obtain bead-on-plate weldment on mild steel plates. Welding parameters were determined for bead width, reinforcement and depth of HAZ with lower-the-better and for depth of penetration with larger-the-better criterion.

Sharma et al. (2009) used 'Best subset selection method' and 'Mallows criterion' for development of model for deposition rate in twin-wire submerged arc welding. The deposition rate had been measured by varying process parameters; welding current, welding voltage, welding speed, contact tube to workpiece distance and wire-diameter for both DCEN and DCEP polarities. The authors concluded that welding voltage and welding speed have considerable effect on the deposition rate.

Nandi et al. (2010) conducted experiment using Taguchi's L25 Orthogonal Array (OA) to produce bead-on-plate weld on mild steel plates by four bead geometry parameters: depth of penetration, reinforcement, bead width and percentage dilution have been determined in terms of voltage, wire feed rate, traverse speed and electrode stick-out. Two hybrid techniques; firstly,

Taguchi method coupled with grey relational analysis; and secondly, Taguchi method in combination with desirability function approach had been applied. The authors also described that in most of the cases; the optimization had been performed using single objective function. For solving multi-criteria optimization problem, it had been suggested to transform multiple objectives into an equivalent single objective function which may be assumed to be a representative of all the quality characteristics of the process, which is to be optimized.

Ghosh et al. (2011) suggested that in submerged arc welding process parameters play a significant role in determining the quality of a weld. So for such applications, optimum welding process parameters must be selected providing desired weld properties. In the work; beads were taken on 15mm thick plate by varying heat input and wire feed rate. Prediction equations were developed for penetration, reinforcement height and width using multi-regression method and artificial neural networks; a comparative study of both techniques had been also performed.

Narang et al. (2012) developed mapping technique for graphical representation of weld bead profile. The authors developed prediction equations for depth of penetration, bead height, HAZ width, bead width, bead contact angle, depth of HAZ and dilution for bead on plate on MS plates. It was suggested that bead contact angle is an important output response among weld bead shape parameters..

Biswas et al. (2012) discussed limitations of Taguchi method along with other techniques such as grey relation theory, desirability function approach, utility theory etc. to solve multi-response optimization problems. Weighted Principal Component Analysis (WPCA) has been applied to eliminate response correlation in the study on optimization of multiple bead geometry parameters of submerged arc weldment using Taguchi method. Experiments had been conducted based on Taguchi's L25 Orthogonal Array design with combinations of process control parameters: voltage, wire feed, welding speed and electrode stick-out to optimize different bead geometry parameters: bead width, bead height, penetration depth and HAZ dimensions.

X. R. LI et.al. (2013) To conveniently monitor weld penetration and acquire the needed feedback for weld penetration control, welding parameters and conditions affecting weld penetration were analyzed and specific variables subject to variation and fluctuation were identified. Experiments were conducted to see what

parameters affect the weld penetration and what their significances are. It was found that the base metal current is the dominant parameter that determines weld penetration with a sufficient accuracy when other major parameters are in their stated ranges. A control system has been established to monitor and control weld penetration using a proportional integral derivative (PID) control algorithm. This algorithm is based on penetration feedback provided by the penetration model that correlates weld penetration depth to base metal current. Experiments on DH36 square butt joints verified the effectiveness of the proposed method.

P. F. Mendez et.al.(2015) presented here high speed video analysis of metal transfer and the design of complex waveforms in SAW, Analysis of the videos show that at 500 A, a very chaotic, nonaxial globular metal transfer involving frequent explosions and bursts is present in both AC and DC polarities. A droplet detachment frequency of approximately 9 Hz was observed at 500A DCEP, and 13 Hz at 500A AC. At 1000A DCEP, a tapering electrode tip with a buried arc was observed ejecting a molten tail through a mechanism resembling an electromagnetic kink instability. Analysis of the voltage signal indicates a $1/f$ pink noise without any indication of the events observed in the videos. Spectrometry of the arc in the weld cavity was performed, and no obvious signs of external gas entrainment were detected.

G. GÖTT et al.(2016) For the first time, a combination of high speed imaging and spatially resolved spectroscopy at 5000 fps was performed on a submerged arc welding process. This was achieved by inserting a thin gauge steel tunnel into the flux and aligning the diagnostics accordingly. Four processes were observed; both direct current electrode positive (DCEP) and direct current electrode negative (DCEN), as well as alternating current (AC) at 600 A and DCEP with a higher current at 1000 A. The videos show an erratic droplet transfer with a lot of spatter that was caught by the cavern walls and directed into the weld pool. The observed processes showed only a slight change in chemical composition of main alloying elements in the solidified weld joint, while the oxygen content varied significantly in the droplet stage and weld joint between the processes. The high speed images indicated a correlation between droplet flux interaction and oxygen content. The spatially resolved spectra showed intense self reversed lines of Na, Ca, and Mn. Fe lines suggested that the arc was also dominated by metal vapor. Especially during the AC process, a fluctuating emission of Mn lines was observed, which correlated with the frequency of the shifting polarity.

IV. GAPS IDENTIFIED FROM THE LITERATURE REVIEW

After study of the existing literature, following gaps were identified towards the design and development of SAW:

- 4.1) Literature concluded that the researchers have carried out most of the work to study the effect of weld parameters on the weld bead geometry but little work has been done on flux composition and its effects on mechanical property estimation and chemical composition of the weld metal.
- 4.2) Literature review reveals that the use of multi response optimization has not been explored for the optimization of process variables and flux compositions.
- 4.3) Cold cracking is still the major issue in higher-strength steel welds. Limited work has been done on flux chemistry modification with an aim to minimize cold cracking.

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