A REVIEW ON SUBMERGED ARC WELDING

Rahul Chahal[1], Pankaj Sharma[2]

Department of Mechanical Engineering, Guru Jambheshwar University of Technology and Management, Hisar 125121, Haryana, India

Abstract - *Welding has become an important technique used by several industries for the production. The weld quality depends on the type of welding technique used. Submerged arc welding finds broad applications in various industries because it is more dependable, offer deeper penetration, gives smoothness on surface and the efficiency is higher. The output parameters such as impact strength, micro-hardness, penetration depth, reinforcement height and tensile strength help in identification of quality of the welding. These output parameters vary with variations in input parameters as input voltage, welding current, wire feed rate, electrode diameter, notch-tip distance and flux condition. This paper has discussed the history of the SAW welding technique developed for the betterment and ease to the people. Various research papers are taken into consideration for the thorough analysis of the inputs used in submerged arc welding of HSLA and variations done for betterment of welding and improvement in the welds.*

Key Words: Submerged Arc Welding, High Strength Low Alloy Steel

1. INTRODUCTION

Welding is a traditional technique used to join metals. The existence of welding is assumed from various past ages like Iron and Bronze Age [1]. A lot of evidences were found that Egyptians were first to learn weld iron [2]. As the time passes a lot of welding techniques came into play to join the different pieces of metal. The joining of metal by hammering was very popular during the middle ages. Over the time different metals like silver, gold, bronze and iron were used for the welding process. Around 300 AD Indian welders also used welding to create the historic iron pillar in Delhi [3]. In 13th century blacksmith used the forged welding to bound metal followed by heating the metals pieces. During the industrial revolution in 18th century various industries needed accurate, fast and advanced technique to meet up the product demand in the market so various innovative techniques came into play [3]. Various patented and effective welding processes like electric arc welding, fusion welding, electrode welding and carbon arc welding were discovered during 19th century. The 20th century was a time of dynamic improvement of materials and processes for welding. Various welding processes and new welding materials have been developed during the 20th century. Still arc welding is used as primary welding process in various fusion welding processes [4].

1.1 Submerged arc welding process

The submerged arc welding (SAW) process is well efficient and flexible method of welding. This is a simple process to melt and join the metals where arc is provided by electrode wore for working under powdered flux blanket [3]. Arc is surrounded by granular flux which prevents flash. Arc is undetectable and stays underneath the bed of grainy flux, protects the metal and arc from the atmosphere so no protection is needed. The granular flux converted into molten slag which increases the molten pool surface [3]. Alternating current is preferred over direct current ton avoid the arc blow. The welding current is provided by an electric contact between the feed wire and metal forming arcing point. In submerged arc welding diameter of feeding wire which is used for electrical contact to the metal could be as large as 6 mm [5]. This approach is commonly utilized for welding steel for various applications such as ship building engineering, submarines, creation of pressure vessels, gigantic water pipelines and shafts. In the semi-automatic SAW process the flux is provided by a small hopper which is placed over the gun used to supply the feed wire but in fully automatic version the flux is provided by remote supply which increases the flexibility and smoothness of the process [6].

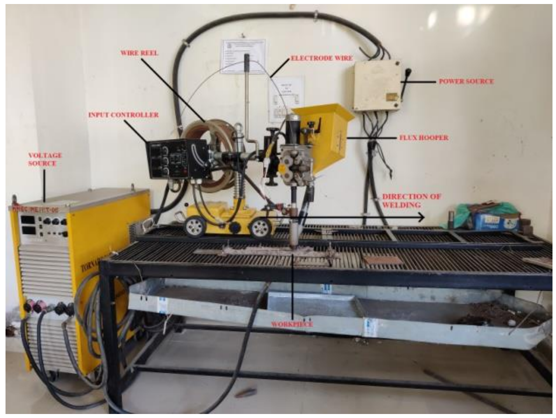

Fig - 1: Welding Machine Setup for SAW

2. Literature review

The various researchers have worked in the field of submerged arc welding of various steels. Their contribution is given below:

Grong et al., (1986) studied the factors which affects the development of low carbon steel and mild steel microstructure. They confirmed that the behaviour of transformation takes place in the welded metal for a given heat cycle depends upon complex collaborations between a few significant factors which includes the aggregate sum of alloying components, chemical concentrations, size appropriation of non-metallic inclusions, the cementing microstructure and the earlier austenite grain size. [7]

Mattes et al., (1990) examined the impact on the properties and microstructure of tempered and as-quenched HSLA 100 by using transmission, light and scanning electron microscopy. The result shows that the toughness depends on the grain size of austenite, copper precipitation and also on carbides and bainite dislocation. [8]

Yang et al., (1992) determined the process parameters and their effect on bead height in SAW of ASTM A36 steel plates. The results stated that it is influenced by electrode polarity, welding current, electrode-diameter, welding voltage, electrode-extension and speed. A big height of bead is obtained by a large extension of electrode, negative electrode polarity, a high speed or current, a small electrode diameter and voltage in many cases. Regression equations were used for calculation of bead height by using process parameters. [9]

Murugan et al., (1993) studied input process parameters namely voltage, nozzle to tip distance and speed in SAW and their effect after weld surfacing. Using technique five level factorial, Mathematical model was developed to predict geometry of welding bead to deposit (316 L) Stainless steel on (IS 2062) structural steel. Investigation of output responses such as reinforcement, width, dilution and penetration was done by taking inputs namely voltage, nozzle-to-plate distance, wire feed rate and weld speed. [10]

Tarng et al., (2002) performed optimization of the SAW process using Taguchi technique (grey-based) for hard facing and also considered various welding qualities. For solving the submerged arc welding process having various weld qualities the grey analysis was adopted. A grey relational grade was used for performance characteristics and optimal parameters are taken using Taguchi method. [11]

Bhole et al., (2006) investigated the hardness and micro-structure of API HSLA-70 pipeline steel after addition of alloying element nickel (Ni), molybdenum (Mo) using SAW welding. It shows the increment in impact toughness and decrement in fracture appearance transition temperature when Mo is added in range of 0.817-0.881 wt%. Mo shows a beneficial effect due to creation of granular bainite and acicular ferrite. The combined micro-structure of the welded specimen involving approx AF (77%) and GB (20%) shows better toughness at temperature around -45^{0}C. [12]

Bose filho et al., (2007) studied combined effect of the alloying elements like nickel (Ni), molybdenum (Mo), titanium (Ti) and chromium (Cr) on development of microstructure of HSLA and also studied the number density, inclusion size distribution, chemical composition and volume fraction. No major effect is shown on micro-structural development when titanium content was added in a range of 50-400ppm. Addition of Mo, Ni and Cr increase the hardenability and the micro-structure of weld metal changes from a blend of bainite, acicular ferrite and carbon martensite to a blend of allotriomorfic, wedmenstatten and acicular ferrite. Silicon and manganese were the primary content of inclusion in welded metal having low Titanium content. [13]

Prasad et al., (2008) examined the effect on hardness, toughness and microstructure of HSLA type steel taking various input parameters in SAW. The welding was done by taking a higher value of heat input (3.0-6.3kJ/mm) and fluctuate the input value of current in range of 500 to 700 A and simultaneously changing the speed of welding (200-300 mm/min). Grain structure and zone affected by heat found to be rough when there is an increment done in heat input. The hardness found to be uniform. The hardness showed an inverse relation with current and a direct relation to welding speed. [14]

Beidokhti et al., (2009) investigated the API 5L-X70 pipeline steel microstructure by adding titanium using SAW procedure. Tensile, HIC and Charpy-V notch test were used for transversely cut specimens to study the relationship between the toughness and microstructure of weld beads. When titanium was added in a range of 0.02-0.05%, shows the finest impact and impact micro-structural properties. The impact toughness was improved by acicular ferrite formation due to titanium-base inclusion. [15]

Kiran et al., (2012) investigated single pass two wire couple lowered circular segment welding cycle of an average HSLA steel plate having width of 12 mm. The mechanical properties of fifty different sets having different input parameters as leading wire current, negative current pulses duration, trailing current pulses and weld speed were studied. The trailing wire current affects the weld bead width and the reinforcement whereas penetration of final weld bead was affected by leading wire current. [16]

Lan et al., (2012) performed a detailed micro-structural investigation of high strength low carbon baintie steel weld metal using transmission electron, optical and scanning electron microscope. Welded joint shows different microstructures as fine polygonal, coarse granular and acicular ferrite. The orientation of weld metal product phase and retained austensite shows close relationship to Kurdjumov-Sachs relationship. The weld metals toughness is higher than that of coarse grain region. [17]

Jindal et al., (2013) developed a prediction equation for form factor, dilution, diffusible H_2 content and micro-structure taking welding parameters as current, weld speed and voltage. The developed prediction equation can be used to get desirable weld properties of HSLA steel during SAW process. The result stated that welding current is vital parameter which controls the output responses. Welding current significantly affect the diffusible hydrogen content, whereas there is little or no cause of arc voltage. Welding current has negative effect over micro-hardness whereas having positive effect on diffusible H_2 content and dilution. The voltage shows incremental effect on the dilution, form factor and diffusible H_2 content but shows decremented effect on micro-hardness. [18]

Holub et al., (2015) performed SAW welding (multi-layered) on W. Nr. “1.6946” using dissimilar welding consumables (Thermanit MTS 616, Topcore 833B). Mechanical properties were evaluated for welding consumables. The evaluated results of tensile and yield strength showed similar properties. The resultant values of ductility and impact energy of the welded specimen were below the specific value when welded with Thermanit MTS 616. [19]

Lan et al., (2016) performed multi-pass SAW process on HSLA with the help of multi micro-alloyed electrodes and micro-structural evolution was investigated using different heat inputs. Strength and hardness of welded joints decreases with increases in heat inputs. Increase in heat decreases the toughness of the heat affected zone. The titanium oxide inclusions of bigger size have better capacity to enhance the formation of the acicular ferrite. [20]

Vedrtnam et al., (2018) studied following parameters namely voltage, current, plate distance and speed on Stainless steel using SAW process. The report stated that bead width increased width voltage increase, while the bead height is directly proportional to current. The bead height and width increases with rise in the weld speed. The hardness of the bead shows growth as the welding input current increases. Response Surface Methodology (RSM) was used for development of the mathematical model. [21]

Choudhary et al., (2018) analyzed effect of various input welding parameters in performing SAW welding procedure for AISI 1023 steel and fractional factorial design was used for that purpose. The welding process was done by taking input parameters as voltage, welding speed, feed wire rate, condition on flux, nozzle to tip distance for output responses namely reinforcement height, bead height and penetration. Mathematical models were developed by using linear regression for the output variables. They used Jaya algorithm, desirability approach and genetic algorithm for the optimization process of the welding input variables. The optimization results provided by Jaya algorithm was better than that of genetic algorithm and desirability approach. [1]

Dirisu et al., (2019) used CMT-WAAM for depositing steel component with the help of single pass deposition strategy. The micro-structural variation effects over the fracture resistance and direction of welding was done by using layer by layer deposition. Investigation of fracture mechanics was done for the deposited parts. The variations in micro-structure and band space are the primary parameter which helps in controlling fracture toughness of steel. [22]

Kolhe et al., (2020) conducted a study which predicted the mechanical properties: heat affected zones and weld geometry of joints. The mathematical model was developed using the statistical methods. The regression equations were prepared for various important controls of welding current, travel speed and the arc voltage. Thus the mathematical equations are useful during the actually fabrication. [23]

Thakur et al., (2020) studied effects of dissimilar parameters of drop geometry on EN31 grade steel plate using automated SAW process. Four welding parameters specifically input voltage, the speed of welding, welding current and nozzle-tip distance were taken. A Mathematical model was prepared with the help of the data gathered using two-level factorial method. The results stated that width of the bead, penetration, reinforcement increased with the weld current. The bead width shows increment with voltage increase, but reinforcement and penetration decreases with voltage increases. Nozzle-plate gap and welding speed produced very less cause on penetration, width and reinforcement. [24]

Rajkumar et al., (2020) welded 6 mm plates of mild steel. Experiment was planned using three parameters at three different levels such as current, welding speed and voltage. Optimal parameters of process were recognized using Taguchi L_9 orthogonal array and its effects on SAW parameters. Mechanical properties of welds were examined using Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis. Weld zone microstructure was observed. [25]

Sharma and Mohal, (2020) studied bead height and bead width on Stainless Steel (SS316) by performing experiment on SAW. RSM was used to optimize the input parameters. The results showed that width and height of bead are influenced by welding current while the voltage and welding speed has direct cause over bead height. [26]

Singh et al., (2020) used nine weld joints for program test. Their work predicted various input parameters to get the finest value of hardness regarding known input parameters. Sensitivity testing was also done for hardness analysis. [27]

Alishavandi et al., (2020) performed bead on plate on heat treatable low alloy steel (HTLA AUI 4135) by SAW machine using Cr-Mo granular flux with S2 (welding wire). Bonded-unfused method was used to prepare the Cr-Mo active flux. Recovery rate of alloying material and the amount of alloy transferred to the welded metal is calculated by generated equations. Various tests such as tensile, micro-hardness, Charpy-V notch (CVN) impact tests were done and investigated. [28]

Mician et al., (2021) focused the research on assessing the impact of cooling rate and heat input over width of the delicate zone, which essentially influences the mechanical properties of the welded specimens. The progression in the HAZ was broke down by mechanical testing and infinitesimal investigation. The deliberate outcomes show a critical impact of warmth contribution over cooling rate, which impressively influenced width of delicate zone in the HAZ. [29]

Jin Jiang et al., (2021) took 24 specimens of High Strength Steel (HSSQ690CFF), divided into 4 groups, providing different input heat value and boundary conditions, strength mismatch ratio for the welding purpose and investigated the thermal effect on the mechanical properties of HSLA. Analysis of cooling rate was done. Residual strain at welding toe is investigated with hot drilling method, whereas Vickers hardness is checked using Vickers test. Studied effect of input parameters such as heat input, boundary condition, mismatch ratio or hardness and microstructure is investigated over heat affected zone. Result shows that change in heat input affects the cooling rate and time. [30]

3. Conclusion

Some conclusions are made after reading the various research papers having different authors taking various input parameters during welding process of different materials. Researchers in their investigations used the SAW welding process by taking different input welding parameters as input welding current, voltage, speed of welding, consumable type and nozzle-to-tip distance which affects the various output responses like microstructure, penetration, width and height of bead, hardness, tensile strength etc. Different types of steels and other alloying materials were used for the experimentation as described in the review and found satisfactory results. The various investigation shows result that the width of bead is influenced by the arc voltage and current affects the penetration and microstructure of the specimen whereas the welding speed also affects the toughness and bead geometry. A lot of work is also stated on the mild steel and stainless steel but the review of literature shows nominal work on the HSLA 572 and no work is found by taking the flux condition (baked/unbaked), so some future work on HSLA 572 can be carried out by taking different input parameters by using SAW.

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