A Literature Review on Submerged Arc Welding (SAW)

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***Abstract*- Submerged Arc Welding can be operated in semi-automatic mode otherwise in automatic mode. But generally, the operation of this SAW can be done in automatic mode. Submerged-arc welding method is fixed and extremely adaptable. This kind of welding involves in arranging the arc among a constantly fed electrode as well as the workpiece. A layer of powdered flux generates a protecting gas shield as well as a slag to protect the weld region. The arc can be submerged below the flux layer & in general, is not noticeable throughout the welding process. In this, the weld quality is extensively influenced by the submerged arc welding parameters like welding speed, welding current, arc voltage, electrode stick out which are closely related to the calculation of the weld bead, This article discusses an overview of submerged Arc welding method.**

INTRODUCTION

Submerged arc welding is another type of arc welding process that uses a continuously fed consumable tubular electrode. It can be operated in the automatic or mechanized mode. It can also be operated on semi-automatic (hand-held) SAW guns with the delivery of pressurized or gravity flux fed. This process is not suitable for flat or horizontal filler welding positions through the horizontal position have been done with a special arrangement in order to support the flux.

In this welding process, the arc zone and weld pool are protected from atmospheric contamination, due to the blanket of granular flux consisting of lime, silicon, manganese oxide, calcium fluoride, and some other compounds. The molten flux becomes conductive and creates current between the electrodes and the base metal. The thick flux layer covers the metal completely, preventing sparks and spatters, and supporting the intense ultraviolet radiation and fumes which are part of the welding process.

EQUIPMENT OF SUBMERGED ARC WELDING

Arc formation between the wire electrode and workpiece happens as in the MIG welding process. But this process has an additional advantage of shielding by the granular flux making the SAW welding as spatter, fumes, and UV light free. The equipment has the following in its inventory.

Submerged arc welding can be used with DC or AC.

1. Power source
2. Welding torch/gun and cable assembly
3. Flux hopper and its feeding
4. Electrode
5. Travel mechanism for automatic welding

1.PowerSource

We need a power source for this submerged arc welding at a 100% duty cycle. The SAW welding process is continuous and the length of one weld may go up to 10 minutes. General power sources with a 60% duty cycle may get derated according to the duty cycle curve of 100%. The voltage sensing wire feeder must be used when a constant current of ac/dc applies. The fixed speed wire feeder uses a constant voltage while the CV system drives with direct current.Both the process DC generator and AC transformer may be used but rectifier machines are more popular. The submerged arc welding machine available in the range from 300 amperes to 1500 amperes.The direct current equipment suits semi-automatic applications while alternating current power source fit for the automation only. The extra power can be achieved by joining both in parallel. With AC type equipment, the use of multiple electrodes is possible in specialized types of applications.

2. Welding Gun and Cable Feeder Assembly

This part of the equipment needs to carry the electrode and even flux to the site of the arc. A small hopper for the flux is attached to the end of the cable assembly. The bottom of the hopper has an outlet for the electrode wire through a current pickup terminal of the arc.The gravity comes into action for the flux feeding. The amount of flux to feed depends upon the height of the gun held above the working station.

3. Flux Hopper

The hopper gun has a soft switch to start the weld. It may use hot electrodes as when it touches the workpiece the feeding starts automatically. In the automatic process, it attaches the torch to wire feed motors and the current pickup tip for the welding process. This hopper is normally attached to the torch which has a magnetically operated valve, open and closed by a control system.

4. Electrode

Bare solid wire or strip is commonly used as electrode of submerged arc welding. However composite metal cored electrodes (similar to flux cored arc welding electrodes) can also be used. Following base metals can be welded with submerged arc welding process:

- Carbon steels
- Low-alloy steels
- Stainless steels
- Nickel-based alloys
- Chromium-molybdenum steels

5. Travel Mechanism

The process of welding is customized at a very fast pace using the travel carriage. This may be available in tractor-like structures. The flux recovery unit normally collects the unused flux and returns it to the hopper for supply. The general movement of the tractor is in a horizontal direction.

SAW Process Variables

The following are some of the key variables of submerged arc welding-

- Arc Voltage
- Electrode Stick-Out (ESO) or Contact Tip to Work (CTTW)
- Polarity and Current Type (AC or DC) and Variable Balance AC Current
- Travel Speed
- Wire Feed Speed (Main Factor in Welding Current Control)

Submerged Arc Welding Consumables

The AWS system defines SAW consumables in a simpler form. The two specifications deal with both wire composition and flux. Another two specifications cover bare wires for stainless steel and nickel-based alloys. For submerged arc welding, there are two that namely-

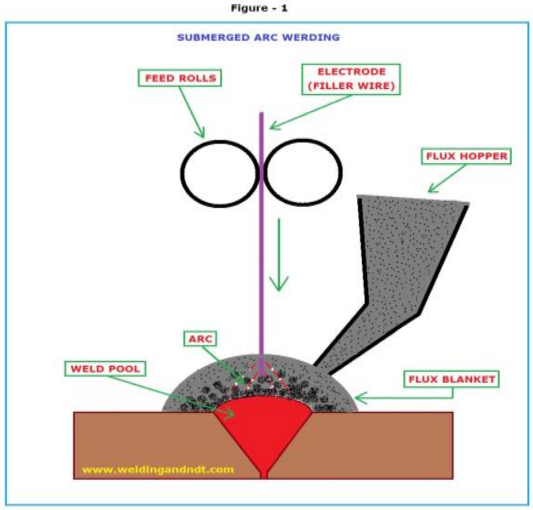
- 17 – Carbon Steel Electrodes and Fluxes
- 23 Low-Alloy Steel Electrodes and Fluxes

The bare wire specifications are as follows-

- 9 Wire Electrodes, Strip Electrodes, Wires, and Rods for Arc Welding of Stainless and Heat-Resisting Steels-Classification
- 11/A5.11M Nickel and Nickel-Alloy Bare Welding Electrodes and Rods for Shielded Metal Arc Welding.

WORKING OF SAW

Figure - 1



Initially, the bare electrode (filler wire) is inserted into a heap of flux that covers the joint to be welded. Then an arc is initiated and a wire feeding mechanism begins to feed the electrode (filler wire) in the direction of the joint at a predefined rate. The feeder can be moved manually or the entire system can be automated. In automated welding, the workpiece moves under a stationary wire feeder or the welding head is moved over the stationary workpiece. Additional flux is continuously fed around the electrodes and gets evenly distributed over the weld joint.The heat generated during welding, melts some of the flux. These liquid flux floats over the molten metal and completely shields the molten weld pool from the atmosphere.

Following factors should be considered before choosing submerged arc welding process for a particular application:

- Chemical composition and mechanical properties required of the final weld deposit,
- Frequency or volume of welding to be performed
- Accessibility of the joint and the position in which the weld is to be made
- Thickness of base metal and alloy to be welded,
- Length of the joint to be welded
- Cost and profitability of the project

ADVANTAGES OF SAW

- Flux is recoverable, recycled, and reused (50% to 90%)
- The capability of deep weld penetration
- Emits minimal welding fume or arc light or no weld spatter
- High deposition rates (over 45 kg/h (100 lb./h)
- High operating factors in mechanized applications
- Imparts high-speed welding of thin sheet steels up to 5 m/min (16 ft/min)
- No high level or edge training is required
- No weld sprinkles due to submerged within flux blanket
- Single-pass welds can be made in relatively thick plates if metallurgically acceptable
- Sound welds are readily made with good design and control
- Suitable for both indoor and outdoor welding works
- When fully automated, high deposition rates and high arc on times

DISADVANTAGES OF SAW

All the welding processes have some sort of drawbacks. Despite having many advantages submerged arc welding limitations are as follows-

- Cannot apply to direct seams vessels and pipes
- Flux handling systems is relatively troublesome
- Flux usage is hard
- Proper root penetration requires backing strips
- Impractical to use in vertical or overhead welding positions. Principally used for butt welds (flat position-1G) and fillet welds (flat/horizontal position-1F/2F)
- Limited to high thickness materials, not applicable to thin materials
- Limited to some particular metals i.e. ferrous or some nickel-based alloys
- Potentially harmful for health problems due to the flux
- Requires inter-pass and post-weld slag removal
- Slag elimination is desirable after welding

APPLICATIONS OF SAW

- It is employed to weld carbon, steel, aluminum, titanium, and minimal alloy materials.
- It holds the ability to create welding joints for corrosion sturdy metals, heat-resistant steels, and other carbon steels.
- Even SAW is implemented for monel and nickel weldings
- Utilized especially for down hand welding place where the plate thickness ranges in between 5-50mm.
- Used in the industries of welding pipes, structural manufacturing, vessel manufacturing, storage tanks, and ship buildings
- Three and nine grades of wires and fluxes, in specific amalgamations, are utilized for SAW of basic steels, average ten-sile steels, lesser-alloyed or HSLA steels, tubes and stainless steels to implement in multiple domains.

LITERATURE SURVEY

[1] Grong et al. 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.

[2] Mattes et al. 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.

[3] Yang et al. 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.

[4] Ch.Indira Priyadarsini et. al. The main issue or main difficulties in the large industries are, the residual stress and overall distortion has been formulated. The main aim of this topic is reduce the residual stress and distortion effect. For experimental study of this thesis SAW has been chosen, thermal effect of submerged arc are depend on the electric arc flux and temperature of work piece material . The SAW is simulated by FEM and ANSYS for the optimization of process parameter material temperature decreased and distance of center point increased.

[5] Tarng et al. 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.

[6] Bhole et al. 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 -450C.

[7] Bose filho et al. 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 microstructure of weld metal changes from a blend of bainite, acicular ferrite and carbon martensite to a blend of allotriomorphic, Widmannstetter and acicular ferrite. Silicon and manganese were the primary content of inclusion in welded metal having low Titanium content.

[8] Prasad et al. 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.

[9] 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.

[10] Kiran et al. 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.

[11] Lan et al. performed a detailed micro-structural investigation of high strength low carbon bainite 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 austenite shows close relationship to Kurdjumov-Sachs relationship. The weld metals toughness is higher than that of coarse grain region.

[12] Jindal et al. developed a prediction equation for form factor, dilution, diffusible H2 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 H2 content and dilution. The voltage shows incremental effect on the dilution, form factor and diffusible H2 content but shows decremented effect on micro-hardness.

[13] Holub et al. 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.

[14] Lan et al. performed multi-pass SAW process on HSLA with the help of multi micro-alloyed electrodes and microstructural 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.

[15] Vedrtnam et al. 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.

[16] Choudhary et al. 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.

[17] Dirisu et al. 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.

[18] Kolhe et al. 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.

[19] Thakur et al. 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.

[20] Rajkumar et al. 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 L9 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.

[21] Sharma et al. 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.

[22] Singh et al. 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.

[23] Alishavandi et al. 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.

[24] Mician et al. 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.

[25] Jin Jiang et al. 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.

[26] Harmeet singh et. al. In this paper work transient temperature and residual stress are evaluated when two dissimilar metal are joint by SMAW process due to presence of residual stress ,life of joint will be decrease for evaluate the residual stress and transient temperature can be evaluated by using FEM and ANSYS software during welding process . Tensile stress is occurring inside the cylinder, peak circumferential stress is outside the cylinder. The residual stress is influenced by the inside and outside weld FEM.

[27] J Dutta et.al. This paper deals with the variation of temperature in heat effect zone in weld joint these properties depend on material properties. Temperature are measure by experimental at predefined location of the plate during welding by mounting of thermocouple. The heat transfer in heat effect zone are carried out convection, radiation and radiation heat transfer are main role of heat losses due to moving plate heat source. The variation of temperature in heat effect zone is 300°c to 600°c.

[28] Rohit jha et.al to study the welding characteristic of different types of weld design and weld metal, the types joint design are v, flat surface to joint by SMAW welding process , varying welding current in all cases. Evaluate all mechanical properties like as % of elongation, tensile strength, yield strength of weld metal and it also show the effect of current on welding speed, yield strength experimentally .the UTS and YS are maximum in V joint design and it conclude that before and at optimum value of UTS, current increase, UTS also increase after optimum value of UTS current increase UTS decrease.

[29] Osman culha et.al this paper are focused on to predict the design parameter like as distortion analysis, thermal stress, temperature gradient, nodal displacement on the plate during saw process. The

residual stress and distortion are occurring near the HAZ by heating during welding process. The design parameter value is achieved by the analysis of thermal elastic plastic by using FEA .It also show stress-temperature distribution. During SAW process T-beam profile are used in welding.

[30] Rohit jha et.al to investigate the effect welding parameter ,welding current ,voltage ,heat input on UTS of mild steel in SMAW process and evaluate the optimum welding current . the UTS of weld metal are to be investigated by using tensile testing machine , the welding current are varying and at 120am the tensile strength of weld metal are high and after optimum value current increase ,UTS decrease.

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

The effect of welding parameter such as current, heat, voltage on mechanical properties of base metal and it seen that if welding current and heat input are increased then mechanical properties also increase. From above literature review we are take temperature thermal stress produce due to temperature within HAZ and also study the effect of temperature inside HAZ of carbon steel ASTN 106 GRADE B. The field application of this work is in pressure vassal, heat exchanger manufacture industries etc.

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