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Research Paper

Experimental investigation and optimization of weld bead and Tensile Strength with bead on plate in Submerged Arc Welding of HSLA 100 steel.

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ABSTRACT: *For the material joining process, the submerged arc welding machine is generally used in industries.The quality of weld is determined by more than a few welding output parameters, including weld bead width, reinforcement, impact strength,penetration, hardness, and tensile strengths. Welding current, voltage, welding speed, feed rate, electrode extension, electrode diameters, and electrodes angle are some of the input welding factors that influence outputs. Many researchers tailor process parameters to their specific needs. The effect of various input parameters on weld quality is discussed in this paper, which is based on several research articles. This work also looked at the impact of heat input rate, weld cooling rate, the microstructure of the weld, and heat-affected zone on joint performance in various research publications. The quality of the weld bead is influenced by the condition of the flux as well as baking.*

KEYWORDS: *Submerged arc welding, flux, reinforcement, tensile strength.*

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I. INTRODUCTION

Rothermund and Jones, Kennedy (1935), discovered submerged arc welding (SAW). This welding can be done manually or semi-automatically. In the vast majority of circumstances, however, submerged arc welding may be done automatically. The method of submerged arc welding is both rigid and flexible. Arranging the arc in the middle of a constantly breast-fed electrode and the workpiece is required for this type of welding. A crushed flux layer forms a shield of gas and protects the weld region by a slag. The arc may be hidden underneath the flux coating and remains generally undetectable during the operation of welding [1].

Submerged arc welding (SAW) is a welding technique that uses an electric arc to melt powdered flux. The technique, which was patented by Jones, Kennedy, and Rothermund, feeds a consumable electrode while shielding the arc zone from the environment by submerging it in a flux of manganese oxide, lime, calcium fluoride, silica, and other chemicals. The flux turns out to be conductive when it is molten [2].

WORKING PRINCIPLE OF SAW

SAW (Submerged Arc Welding) is a metal joining procedure in which arc is covered and concealed by granular and fusible flux. The arc between the replaceable wire electrode as well as the workpiece generates heat for welding process. Machine's primary components are visualized in Figure 1.1. The arc is protected from the elements by a molten flux or slag cap. This flux improves in the refinement of weld metal and protects it from infectivity caused by the environment. There can be some substances in flux that assist to improve the weld's mechanical characteristics. The flux hopper, which stores flux, the spool of electrode wire, and the control box, which houses electrical circuits, are all important components of this welding process.The information presented on the control box assists the operator in determining welding current, voltage, and speed. The operator can adjust or vary them as needed by viewing at the display. Tractor movement can be either manual or automated, and controls are available for both [3].

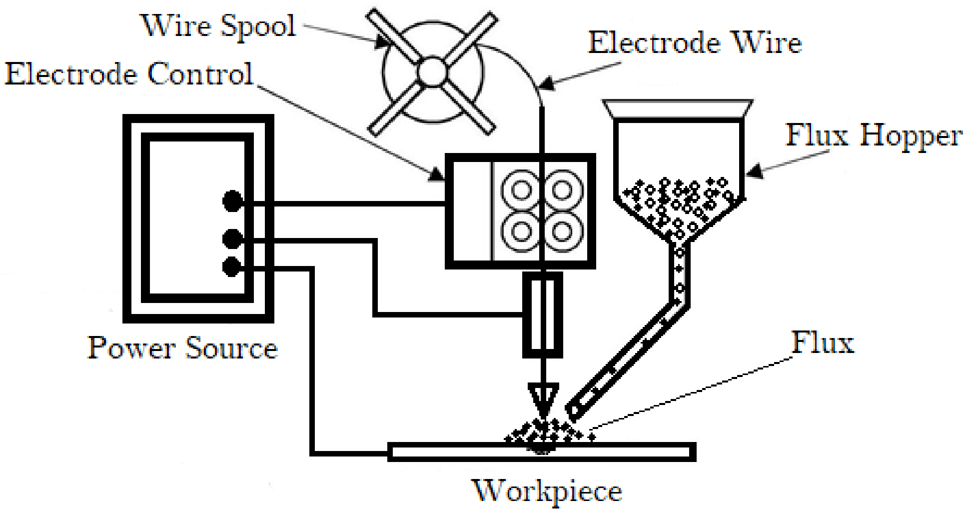

Figure: Block diagram of Submerged Arc Welding

Powered drive rollers feed the electrode in this procedure. Electric current generates an arc, which is subsequently sent to an electrode through a contact tube. DC (Direct current) with electrode positive, i.e., reversal polarity, straight polarity with electrode negative, or AC (alternating current) with electrode negative might all be used in this treatment (AC). The slag that remained un-fused is removed once the welding procedure is done and the weld metal has solidified. Depending on its state, the unfused slag can then be utilised. Crushed, resized, and blended back into new flux, the hardened slag may be crushed, reshaped, and mixed back into fresh fluxes. Semiautomatic and completely automated submerged arc welding also possible [4].

EQUIPMENT OF SUBMERGED ARC WELDING

The type of SAW equipment required depends on whether the process is automated or semi-automated. A welding power sources, wire feeder, and self-control system, an automated welding head, a flux hopper with fluxes feeding mechanisms, a flux recovery system, and a travel mechanism, which generally consists of moving carriages and rails, are all included in automated submerged arc welding’s.

Power Sources

A submerged arc welding (SAW) system's power supply has a significant impact on its operation. The submerged arc welding procedure gives discovered to work with both DC and AC power supplies. A direct current(D.C) power supply can be either transformer rectifier, motor or engine generators, and it can output constant voltage (C.V), constant current (C.C), or a selectable steady voltage/steady current output. Constant-Voltage Direct Current power supply are ideal for situations If the arc current is less than 1000 amp, although they can also handle greater currents without issue. Constant Current or Direct Current power supply is a viable option for high-speed welding of thin steels. Alternative Current (A.C) power supplies are typically transformer based and can produce either (constant current) CC or CV (constant voltage) square wave.SAW is a highest current, high duty cycle process that requires a power source able of delivering high amperage at 100% duty cycle. High current applications for the AC power SAW method include multi wire purposes, fine (narrow) gap welding, and many more applications with arc blow difficulties [6].

Wire feeder and a control system

Simple wire feed speed controls are used to regulate semiautomatic submerged arc welding. Controls for constant voltage power supplies keep the wire feed speeds constant, whereas control for constant current power supplies monitor the arc voltages and modify the wire feed speeds to keep the voltage constant.

A typical wire feeder & control system has cutting-edge wire feeders, microprocessor-based digital controllers, and other critical components like the wire feed motor and wire drive assembly, among others. To keep the welding voltage or wire speed at preset settings, these controllers incorporate feed-back loops connected to the power supply and wire feed motor.

These controls regulate power supply (voltage), wire feed speed (current), join start-stop, automated or guide travel on-off [6].

Welding head and flux feeding mechanism

The wire feed motor then feeds roll meeting and the torch meeting or contact tip, and fixtures for proper positioning or locating the crown are all included in the SAW welding head. Fluxes nozzle remains generally positioned at the weld head to deposits flux in advance of concentrical with the welding wire.The wire feed motors are usually permanent magnet motors with an integrated reduction gearing that feed wire at rates ranging from 20 toward 550 inch/min (8to235mm/sec). A tiny, gravity-fed flux hopper positioned atop the flame provides flux [6].

A compact 1.8kilogram significance feed fluxes hopper positioned at the blow incinerate and remote fluxes storage reservoir (chamber) which employs compress air toward drive flux to the welds area for fluxes feed. The fluxes is provided through the flames nearby the welding wires in both circumstances.

Travel mechanism

A carriage of tractor types, side beam type carriage, manipulator is the most common travel mechanisms in SAW. Trackless units employ guide wheels or some other sort of mechanical joint-tracking mechanism, whereas tractor-type carriages drive.

Weld head, controls, wire supply, and flux hopper are all positioned on the tractor in most circumstances. Tractors have a maximum travel speed of roughly 45 mm/s [6].

Tractors are most commonly use up in field welding, where their relative mobility is required due to the inability to move the workpiece. On the carriage are placed the weld head, wire, flux hopper, and control.

II. LITERATURE REVIEW

Austin J.B et al (1956) current, voltage, and transit speed all affect the entry. Warm conductivity, curve length, and bend power are some of the other parameters that impact circular segment infiltration, according to the researchers. Their research discovered that if the work material's warm conductivity is higher, the bend entry would be shallower. They claimed that if the curvature is too small, the infiltration will be poor [7].

Ahmad M.A. et al (2019) for the optimization of submerged arc welding(SAW) procedure, this study uses the orthogonally factorial approach, ANOVA difference, S/N Ratio, and prestige evaluates. By using this methodology, parameters are classified based on their significances on reactions, difference evaluates are conducted, optimal standards for selected manageable issues or reactions discovered, finally ideal response standards are authenticated by carrying out original weld runs and comparing the definite results to the calculating optimal standards [8].

Biswas et al (2007) to weld in the SAW method has been studied and analyzed. He also looked at the impact of various submerged arc welding processing parameters on weld's output characteristics. The Taguchi technique is used to determine the effects of changed processing parameters on output characteristics of a SAW. In submerged arc welding, Biswas used the Taguchi approach toward estimate influence of processing factors on weld [9].

Daemen A. et al (1970) the result is that at 850℃, the transition from Ferrite toAustenite take place fast in 316L composites. It also possible to explain occurrence of the sigma’s stage in the store weld metals by considering together the short refrigeration rates during stripe welding and the detail that ferrite groups have reduced measures in weld metal then projected/fashioned preparations. The welding consumables should be unusually designed to avoid this type of modification, which is foreseen for the erosion obstruction of the composites. The r-c combination was shown to be particularly sensitive to consumption are initial sites of ferrite. All of the etchant appears to have considerable erosion effects in those areas. They conclude that lowest ferrite amalgams, such as 316 L, have greater erosion rate after seeing the results [10].

Renwick B.G. et al (1976) they experimented with various features while altering various parameters and discovered that when the welding current is increased, the weld bead penetrations or melting rate rising. Renwick discovered that the greater the welding voltages, the flatters, and broader the weld beads become, and the fluxes consumption rises with it [11].

Bailey N et al (1978) in influent of the composition issues on breaking through hardening in reduced curve welding may be easily examined using the trans-restraint test, according to the researchers. An described that structure-based break vulnerability esteems and breaking distinct preparations created with the help of different weld constructions also fundamentally associated. They said that the testing can’t define the influences of issues that change the form of the weld then such differences change testing circumstances. That hypothesis contains several flaws that have been identified; nevertheless, changes may be made to consider the trans-restraint findings obtained from these experiments, which result in various weld forms. They proposed specific actions to limit breaking in hardenings, such as hole filling strategies, the use of low carbon filler metals, Sulfur or Phosphorous constituents, and the used of appropriate force methods to upgrade the testimony by expanding or keeping statement rates while avoiding the foreseen impacts of enormous weakening's and huge profundity to width proportions [12].

Viano D.M. et al (2000) the weld in two wire tandem submerged arc welding of high strength low alloys (HSLA) steels was examined and analyzed. They discussed the impact of overall heat input in welding, as well as welding speed, on the microstructure of the weld, its mechanical characteristics, and the weld profile. They discovered that increasing the welding speed provides a weld profile devoid of undercuts for all heat inputs and that the average inclusion size rises as the heat input increases, while the density of the inclusions reduces. They discovered that when the total heat input of the welds increases at a certain welding speed, the acicular ferrite volumes percentage, hardness, or Charpy impact toughness are weld decreases [13].

Sharma L. et al (2020) the constrained mixture design approach was used to develop submerged arc welding fluxes in this study. The intense vertices design approach was used to create 21 flux compositions created preceding the CaF_2–CaO-SiO_2 and Al_2O_3-CaO-SiO_2 flux systems. The binary admixtures C.Al, S.CF, S.Al, and C.Al all consume a considerable influence on Silicon concentration in multi-layer weld deposits, with SAl being the effective synergistic interaction. Copper concentration is reduced by both single and twin interactions. C.CF.Al and S.CF.Al in ternary mixture components have an anti-synergistic effects on copper content, whereas S.Al (S-Al) and C.Al (C-Al) constituents have an increasing effect. During multi-layer weld deposits, single mixtures components C, S, C.F, and Al boost Molybdenum concentration. The S.Al twin mixtures has a positive effect on Mo content. The components C, S, CF, and Al in single mixtures have an anti-synergistic influence on Titanium concentration. All of the twin components have a detrimental impact on the Cr content. The abbreviation C.CF.Al is only ternary component that has a synergistic effect, increasing the amount of chromium in the body. The flux constituents' chemical formulas are shown; Calcite, Silica, Fluorspar and Calcinated Bauxite (Al_2O_3) [14].

Grong O. et al (1986) a study of weldment in milds and high strength low alloys steels during submerged arc welding processes was given, as well as a comprehensive analysis of the categorization of weld microstructures generated in mild steels and high strength low alloys steels during submerged arc welding (SAW) processes. They discovered that weld's final microstructure was influenced by the cooling rates from 800C to 500C (DT 8/5), as well as Austenite particle extent, nonmetallic component distributions,or chemical structure. In HSLA steel welds, the factor DT 8/5 is thought to be an effective measure of the amount of an Austenite to Ferrite transition [15].

Gowrisankar I. et al (1987) the lowest Delta Ferrite contented roots area of weld grows as number of passing during welding increases, and the delta ferrite content differential between the surfaces and root of the weld reduces as the number of passes increases. They also discovered that when the number of passes in welding increases, the hardness, and tensile strength qualities rise, but ductility and impact properties drop [16].

Chandel (1987) the melting rates is regulated by welding currents, wire diameters, electrode extension, arc voltages, power supply, electrode polarity, and fluxes category are submerged arc welding process. They described that increasing the welding current will enhance the melting rate for given wire diameters, electrodes polarity, and electrodes extension. They went on to say that for the same welding current, bigger electrode extensions, negative electrodes, and smaller diameter electrodes result in higher melting rates and that the arc voltages and kind of power sources utilized had no effect on melting rate [17].

McGrath et al (1988) for series of welds produced in thickness sections of steel make use of the submerged arc narrow groove method, mechanical characteristics such as strength, notch toughness, and associated microstructure were evaluated. They discovered that all weld metals deposit using variety of wire attractions (different Si, Mn, and Mo concentrations) or fluxes basicity attained desired flexible characteristics of 275MPa yield and 482MPa ultimate tensile strength(UTS). Claimed that weld failed to meet at necessary low point temperature notch toughness characteristics had coarse grain border Ferrite and Ferrite by second stage microstructures [18].

Belton et al (1963) discovered that the quantity of SiO_2 in the fluxes affects arc penetration, and that the width to depth of penetrations ratio increasing as the amount of SiO_2 in the flux decreases. They stated that the basicity of the flux has an effect on the penetration width to depth ratio [19].

Mehta N.P. et al (2012) the purpose of this research is to design, evaluate, and optimize flux for submerged arc welding of HSLA steels. The extreme vertices model approach was used to create statistically calculated flux combinations by combining eight flux mechanisms, altering four mechanisms MgO,Al_2O_3,CaF_2,CaO while putting TiO_2,SiO_2,MnO constant. For welding of HSLA steel, estimate calculations intended for weld mechanical characteristics in terms of separate flux components, binary mixes has developed. At a 95% confidence level, the difference in mechanical properties in among expected and experimental values for weld metal cannot insignificant. CaO has a negative impact toughness effect on its own, whereas binary combinations of MgO,CaF_2,CaO have positive impact toughness affecting weld metal UTS and increased impact toughness. Although the fluctuation element Al_2O_3 has increasing effect on both UTS and impact toughness.MgO has an increasing affecting on U.T.S. while having a decreasing affect on hardness. The addition of Al_2O_3 to the flux improves grain refinement, increasing quantity of A.F. in weld metal. Four flux mixture solutions are offered, resulting in yielding optimised weld metal mechanical characteristics and diffusing hydrogen contented of HSLA steel weld. The diffusing hydrogen contented of all flux constituents increases, but the diffusible hydrogen content of binary combinations $Ca.F_2$ mixes decreases. The amount of diffusible hydrogen in CaF_2 decreases up to 28%, but after that, the quantity of diffusible hydrogen increases [20].

Gupta et al (1993) this study looked at the effect of fluxes and other welding parameters the SAW method. They examined five dissimilar welding fluxes and observed that the basicity the flux and dissimilar welding parameters had a significant influence on the depth of penetrations and breadth of the weld bead in their examination of SAW process using mild steel. They observed that welding conditions, not flux basicity, had an influence on the reinforcement. They also observed that when the basicity of the flux is higher than when it is lower, the breadth of the heat affected zone is less for lower welding current ranges. [21].

Matttes et al (1990) it was discovered that alloying additions and thermo mechanical processing of HSLA steels result in positive metallurgical modifications and enhanced combinations of engineering material qualities through microstructural control. Morphology addition, carbon nitride solubility, grain refining, precipitation hardening, and substructure strengthening are all physical metallurgy ideas employed in HSLA steels, according to the researchers. They also discovered that introducing small amounts of niobium, titanium, or vanadium induces structural and physical changes. Above all, this is the key to the micro alloying success of HSLA steel [22].

Joarder A. et al (1991)this studied was to examine the effects of various welding parameters on chemistry welded metal. They discovered that operational parameters have important effect on the chemistry of weld deposition. They also discovered that the microstructure of the weld metal determines the mechanical properties created during welding [23].

Yang at el (1992)studied the effect on the width of weld beads of welding currents. He found that their increment in welding current and for given electrode diameters the width of weld beads increases, width value of electrode extension reaches maximum and then decreases for further increases in welding current value[24].

Murugan et al (1993) to analyse the weld bead of a 20mm thickness plate of steels IS 2062, explain how welding speed, welding voltage, wire feed rate affect and electrode extension the weld bead dimensions. They determined that slowing down the welding process enhances the breadth, penetration, and height of the weld. They also observed that these parameters grow as the wire input rate rises. They discovered that as the electrode extension is increased, the depth of penetration decreases but the weld breadth increases [25].

Konkol P.J. et al (2007) the FSW machine was designed to produce welds of comparable quality to standard submerged arc welding. The presentation demonstrates that HSLA-65 steel can functionally be joined by FSW for structural application. When utilising the PCBN tools to establish process parameters, there was a varying degree of success. When utilising the PCBN tools to establish process parameters, there were varying degrees of success. Mega Stir recommended a tool temperature of 800°–900°C (1472°–1652°F) as measured by the thermocouple. Tool breakage occurred in welds done at lower temperatures. Tool wear and separation of the PCBN insert from the locking collar were seen at higher temperatures. The W-Re pin penetrating through the HSLA-65 and into the backing bar after roughly six feet of welding was related to tool wear, which caused the tool to penetrate further into the workpiece during welding. Overmatching transverse weld tensile strength was observed in the W-Re FS and SA weldments, which cracked in the base metal. The SA weldment passed the face-and root-bend tests, but one of the FSW face-bend specimens had a rejectable rip that was attributable to embedded tool shoulder material. The introduction of a W-Re shoulder material is intended to solve this problem. The current testing shows that FSW is technically feasible for structural applications with HSLA-65 steel [26].

Murugan et al (1997) to investigate and discover that even when high welding speeds and high voltage are combined in SAW, the result is reduced dilution in the weld. Low reduction situations, they wrote, advantageous in surface covering because they provide the cladding material high ductility and resistance to intergranular corrosion. [27].

Dallam.et al (1983) impact of flux configuration on various factors such as the SAW weldment microstructure and toughness. They used acid dissolving techniques to investigate the chemical and crystalline composition of the particles [28].

Gunaraj et al (1999) to investigate the use of SAW for pipes in two different pipe welding configurations: bead on joint (BOJ) and bead-on plate (BOP). Using mathematical models created for SAW of pipes, they evaluated the influence of well regulated process factors arranged heat input or extent of heat affected zone(HAZ) [29].

Lee et al (2000) they discovered that when welding current increased, their ratio of heat affected zone weld beads size decreased. Observation was that when there is increment in welding current, the size of the heat affected zone and weld beads increased. They also investigated how the size of the (HAZ) heat affected zone and the size of the weld bead changed as the welding current increased, and create that weld beads size increased more than the size of heat affected zone (HAZ) [30].

Chandel et al (1997) it was investigated and examined the activities of various parameters of welding or established software to predict the effects of electrode polarity, welding current, electrode diameter, and electrodes extension on melting rate, weld bead width, weld bead height, and welding penetration in SAW. Yang et al. developed techniques for evaluating weld bead geometry, which are completely implemented in the programed. The software's restriction is that it only forecasts the weld bead shape for welds that are bead-on-plate (BOP) [31].

Sridhar P.V.S.S. et al (2019) to test the effecting of welding current on bead profile and mechanical characteristics, investigators used double-sided SAW on AISI 304 Austenitic stainless-steel plates. Reinforcement area, reinforcement height, penetration area and depth, and bead overlap area all improve in a nearly linear pattern as welding current rises. The ratio of bead width to reinforcement and bead width to penetration increased firstly as welding current increasing, but then remained almost constant or decreased somewhat. Tensile properties were shown to increase when welding current was increased. The fracture morphology of specimens shows non-homogeneously dispersed dimples over the rupture surface, indicating a ductile rupture. Dendrites of delta ferrite may be seen in the emaciated and lathy morphology of synthesis zone of the double sided submerged arc welding specimens. The fusion zone microstructure shows no indication of equiaxed grain development [32].

Aksoy M. et al (1999) to investigate weld, to develop a link among microstructure and original particle extent, weld metal toughness, weld metal hardness, heat affected zone(HAZ). By keeping the heat input constant, they determined that initial grain size has a significant effecting on microstructures of the weld, toughness of the weld, HAZ of low carbon steels andtoughness of the weld metal [33].

Vera et al (2001) the purpose of this study was to look at the mechanical characteristics, microstructure of base metals, heat affected zone(HAZ), weld metals on SAW pressure vessels, along with the influence of Postweld heat treatment (PWHT). The steel utilised was ASTM A537 C1. According to the findings, the flexible as well as effect characteristics of base metal fall marginally, whereas the effect strength of welded metal increased [34].

Jun H.J. et al (2003) microstructures joints of welding was investigated, it was discovered recognising the microstructure of the weld zone is a key task. They said that the micro-structure of the welded connection is researched in order to predict its strength and thoughness, and that the steels used for intersections require microstructure using well particles and beneficial required characteristics. Due to microstructural changes in the HAZ, the joint because of absence of stiffness afterward welding (HAZ). They went on to say, the rough grained heat affected zone (HAZ) takes more stiffness than fine grained HAZ [35].

Gunaraj et al(2002) to research and create mathematical models for optimising the results gained in the form of weld bead quality in the submerged arc welding process for pipe welding. They created Response Surface Methodology (RSM) to investigate and optimise welds bead quality in SAW of pipes using mathematical models they devised [36].

Jerzy et al (2005) to investigate the joint of welding and the effect of welding parameters upon resulting weld. It concentrated the impact on total heat input of the weld produced by the (SAW) method. For their research and examination, they chose duplex steel UNS S31803. They discovered the weld defectiveness of duplex steel grows as plate thickness of weld increases as a consequence of their analysis and testing. They discovered that increasing the heat input during welding minimises the happening of unacceptable welding flaws in the joints, reducing expense of assessing the strength of weld and thereby decreasing its cost [37].

Kanjilal P. et al (2006) to investigate different flux compositions in relation to various welding parameters. Their research and examination resulted in the creation of a rotatable design which is based on statistical investigation of flux mixtures in order to predict the mixed effects of flux mixtures and welding parameters. They tested bead-on-plate welds retained on low carbon steel plates using a mixture of parameters of welding, flux compositions [38].

Mehmet Turker (2017) in order to test micro-structural and mechanical qualities, S960QL Steel was welded with a SAW process in this study. The results of the chemical studies provided mean values for the weld metal and filler wire arrangements. Since its examines be located performed out through the varied zone, the effect of modifying experimental parameters on spreading of alloying fundamentals existed not observed. At the HAZ, extreme stiffness values were measured. The hardenability of the HAZ is reliable through the literature. The obtained hardness distribution was found to be consistent with the literature. The WMCL hardness values were similar to those of the basic metal. The HAZ area had 350-448HV0.3 at the root pass row from centre line on base metal. The propensity for fractures in HAZ is revealed by such stiffness values for together multilayer passes and basis passes. The tensile strength of central and bottom flat type specimens was greater than the producer's and literature's minimum base metal values (>980 MPa). The top flat type samples had a lower density than the other flat types. The flat type specimens had smaller elongations than the base metal [39].

Ana et al (2005) the purpose of this research was to investigate the fluxes used in SAW and to classify the fluxes based on their structure, features, and chemical compositions. Due to the existence of flux, description allowed to measure the ions and restricted electrons existing in the plasma arc created SAW. Their research and analysis aid in the prediction and determination of reactions occurring in the weld pool. They came to the conclusion that flux selection is more important [40].

Datta et al (2006) the weld bead and SAW welded metals were tested and assessed. They created a statistical model based on the data and forecasts for predicting and predicting the amount of weld bead generated in submerged arc butt welds [41].

KeshavPrasad et al (2006) to investigate a simple carbon steel weld joint. In SAW, KeshavPrasad discovered effects on SAW on the microstructures and stiffness of the weld. He employed heat response as study's processing parameters. In his research, the author employed 16mm thickness plates of ordinary carbon steels and studied it after welding it with a SAW procedure. He discovered that the heat affected area has the highest stiffness in welded metal, and that the stiffness varies since the weld centerline to disreputable metal. When heat response in submerged arc welding is increased, the grain structure of the weld metal becomes coarser [42].

III. CONCLUSION

After studying the different research papers considerablevaluableinformation's about the Submerged Arc Welding procedure and its procedure parameters have been collected. This review paper would be cooperative for the constant researches on improved the production quality and optimization of method parameters of SAW on HSLA-100 steel.

- The various input parameters in SAW process can determine the required output parameters with accurate and precise readings on good weld quality.
- The SAW process uses arc current, feed rate, travel speed, electrode diameter, voltage, flux condition (baked or unbaked), and electrode angle as input parameters.

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