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A Review on Submerged ARC Welding

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Abstract:
Submerged arc welding (SAW) is one of the major welding processes used in an industry if thickness of parts joined exceeds 20mm. A lot of research is going on to increase deposition rates and productivity with use of multiple wire submerged arc welding with metal powder as addition. Also a lot of study has been carried out on flux composition as it affects the properties of weld. This paper presents the work carried out to study effect of welding parameters on mechanical properties of weld metal, effect of weld input on the quality of weld and effect of flux composition on the quality of weld. Also this paper gives brief overview of parameters like power source, welding electrode, flux, welding current and voltage, welding speed, bead geometry affecting the properties of weld.

Keywords: Submerged arc welding, welding parameters, flux

I. INTRODUCTION

Submerged arc welding (SAW) process uses heat generated by an electric arc established between a bare consumable electrode wire and the work piece. Since in this process, welding arc and the weld pool are completely submerged under cover of granular fusible and molten flux therefore it is called so. During welding, granular flux is melted using heat generated by arc and forms cover of molten flux layer which in turn avoids spatter tendency and prevents accessibility of atmospheric gases to the arc zone and the weld pool. The molten flux reacts with the impurities in the molten weld metal to form slag which floats over the surface of the weld metal. Layer of slag over the molten weld metal increases protection of weld metal from atmospheric gas contamination and so improved properties of weld joint. It is the most efficient fusion welding process in plate and structural work such as shipbuilding, bridge building, and pressure vessel fabrication, assuming the work pieces can be properly positioned and the equipment accurately guided [1]. SAW is known to be a high current (sometimes even greater 1000A) welding process that is mostly used for joining of heavy sections and thick plates as it offers deep penetration with high deposition rate and so high welding speed. High welding current can be applied in this process owing to three reason a) absence of spatter, b) reduced possibility of air entrainment in arc zone as molten flux and slag form shield the weld metal c) large diameter electrode. Continuous feeding of granular flux around the weld arc from flux hopper provides shielding to the weld pool from atmospheric gases and control of weld metal composition through presence of alloying element in flux. Complete cover of the molten flux around electrode tip and the welding pool during the actual welding operation produces weld joint without spatter and smoke. In following sections, important components of SAW system and their role have been presented (Fig.1).

Submerged Arc Welding (SAW) is one of the major metal fabrication techniques in industry due to its reliability and capability of producing good quality weld. The ability to join thick plates (as thick as 4mm) in a single pass, with high metal deposition rate has made this process useful in large structural applications.

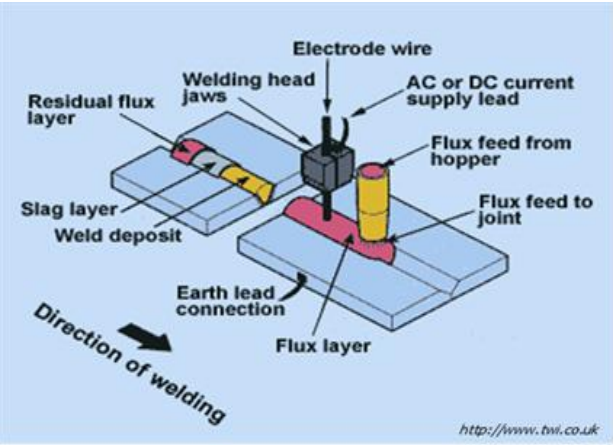

Figure.1. Principle of submerged arc welding

Indeed various research works have been explored on various aspects of submerged arc welding, yet investigations are still being carried on to study the phenomenon that occurs during the process of submerged arc welding, and many other related matters, so that the process becomes controllable more precisely, and can be monitored well, both manually as well as automatically. Now a days, lot of attention has been given to increase deposition rates and productivity with use of multiple wire submerged arc welding [2] with metal powder addition. Also a lot of research has been going on flux composition as it adversely affect properties of weld metal and so cost involved in welding. One of the key problems faced by industries is storage of flux as it absorbs moisture. Moisturized flux can be recycled and redried and can be used again. [3] The major trends of research related in the field of submerged arc welding includes: a) Effect of process parameters on mechanical properties of weld metal b) Effect of heat input on quality of weld c) Effect of flux Composition on quality of weld.

II.LITERATURE REVIEW

2.1. EFFECT OF PROCESS PARAMETER ON THE MECHANICAL PROPERTIES OF WELD METAL –

N.A.McPherson, K.Chi, T.N.Baker [4] assessed submerged arc welding of austenitic stainless steel and duplex steel and

found that even though some intermetallic compound is present in weld zone but they did not adversely affect the weld metal properties. It has been suggested that segregation mechanism is responsible for their presence in this case.

S. W. Wen, P. Hilton and D. C. J. Farrugia [5], while doing finite element modeling of a submerged arc welding process concluded that the geometrical distortion and residual stresses and strains caused by welding can be minimized through process optimization. So they demonstrated that finite element analysis can be applied to better understand the SAW process and hence be a useful tool for future process development and control with the view of optimizing product properties.

Ana Ma. Paniagua-Mercado, Victor M. López-Hirata and Maribel L. Saucedo Munoz [6] while conducting study on influence of the chemical composition of flux on the microstructure and tensile properties of submerged-arc welds shows the importance of the selection for flux composition in order to improve the mechanical properties of steel welds.

P. Kanjilal, T.K. Pal and S.K. Majumdar[7] while studying the combined effect of flux and welding parameters on chemical composition and mechanical properties of submerged arc weld metal concluded that the results show that flux mixture related variables based on individual flux ingredients and welding parameters have individual as well as interaction effects on responses. Amongst welding parameters, polarity is found to be important for all responses under study.

Prasanta Kanjilal; Tapan Kumar Pal, Sujit Kumar Majumdar [8], studying the prediction of mechanical properties in submerged arc weld metal of C-Mn Steel, as a function of flux ingredients such as CaO, MgO, CaF2 and Al2O3 in submerged arc welding carried out at fixed welding parameters, and concluded that among the flux ingredients, MgO appears to be important on its own in influencing the mechanical properties.

De-liang Ren, Fu-ren Xiao, Peng Tian, Xu Wang and Bo Liao [9], investigate the effects of welding wire composition and welding process on the weld mental toughness of submerged arc welded pipeline steel and concluded that the contents of alloying elements need to vary along with the welding heat input. The microstructures mainly consisting of ferrite can be obtained in weld metals using the wires with a low carbon content and appropriate contents of Mn, Mo, Ti-B, Cu & Ni, resulting in the high low-temperature impact toughness of weld metals.

2.2. EFFECT OF HEAT INPUT ON QUALITY OF WELD

Jerzy Nowacki, Pawel Rybicki [10] analyzed influence of welding heat input on submerged arc welded duplex steel joint and found that even though heat input was change from 2.5 to 4.0 kj/mm has no negative influence on mechanical properties of joint. Usage of larger welding heat input provides the best quality, what decreases the joint control and repair cost.

Deepti Jaiswal [11] studied effect of process variable on the heat input and micro hardness of weld metal and heat affected zone for bead on joint welding where calculated and analyzed using design of experiment software on pressure vessel plate SA-516 grade 70 and found that the micro hardness of weld metal and heat affected zone decreased when the no of passes increases that is total heat input increased.

S.shen, I.N.A. Oguocha [12] studied the effect of heat input on weld bead geometry of ASTM A709 Grade 50 steel joint and found that bead width penetration HAZ size increased with increasing heat input. Also electrode melting efficiency increased with increasing heat input for single wire welding but plate melting efficiency did not change.

2.3. EFFECT OF FLUX COMPOSITION ON QUALITY OF WELD METAL

P. Kanjilal, T.K.Pal, S.K. Majumdar [13] studied combine effect of flux and welding parameter on chemical composition and mechanical properties of low carbon steel plate and found that weld yield strength and hardness are mainly determine by welding parameters where as impact toughness is determine by flux mixture variable.

Brijpal Singh, Zahid akthar khan [14] reviewed the effect of flux composition on weld bead properties and geometry and found that flux constituent has major effect on flux behavior and bead shape geometry. The load carrying capacity of welded joint doesn't only depend on microstructure but also affected by physical behavior of the flux the main characteristic which are affected by flux consistent are arc stability, slag detachability, capillarity, viscosity, basicity index.

Kulwant Singh, Sunil pandey [15] used recycled slag after necessary modification and achieved weld metal chemistry within the acceptable range. Also arc stability and slag detachability found to be good with the recycled slag.

III.PARAMETERS AFFECTING SUBMERGED ARC WELDING

3.1. Power Source

Generally, submerged arc welding process uses power source at 100 % duty cycle. Depending upon the electrode diameter, type of flux and electrical resistivity submerged arc welding can work with both AC and DC. Alternating current and DCEN polarity are generally used with large diameter electrode (>4mm). DC with constant voltage power source provides good control over bead shape, penetration, and welding speed. Polarity affects weld bead geometry, penetration and deposition rate. DCEP offers advantage of self regulating arc in case of small diameter electrodes (< 2.4mm) and high deposition rate while DCEN produces shallow penetration.

3.2. Welding electrode –

The diameter of electrodes used in submerged arc welding generally ranges from 1–5 mm. The electrode wire is fed from the spool through a contact tube connected to the power source. Electrode wire of steel is generally copper coated for two reasons a) to protect it from atmospheric corrosion and b) to increase their current carrying capacity. However, stainless steel wires are not coated with copper.

3.3. Flux-

Role of fluxes in SAW is largely similar that of coating in stick electrodes of SMAW i.e. protection of weld pool from inactive shielding gases generated by thermal decomposition

of coating material. SAW fluxes can influence the weld metal composition appreciably in the form of addition or loss of alloying elements through gas metal and slag metal reactions. Few hygroscopic fluxes are baked (at 250–300^0 C for 1-2 hours) to remove the moisture. There are four types of common SAW fluxes namely fused flux, agglomerated flux, bonded flux and mechanical fluxes. Manufacturing steps of these fluxes are given below.

• Fused fluxes: raw constituents-mixed-melted-quenched-crushed screened- graded

• Bonded fluxes: raw constituents-powdered-dry mixed-bonded using K/Na silicates-wet mixed-pelletized-crushed-screened

• Agglomerated fluxes: made in similar way to bonded fluxes but ceramic binder replaces silicate binder.

3.4. Welding Parameter –

Welding parameters namely electrode wire size, welding voltage, welding current and welding speed are four most important parameters (apart from flux) that play a major role on performance of the weld therefore these must be selected carefully before welding.

3.4.1. Welding Current –

Welding current is the most influential process parameter for SAW because it determines the melting rate of electrode, penetration depth and weld bead geometry. However, too high current may lead to burn through owing to deep penetration, excessive reinforcement, increased residual stresses and high heat input related problems like weld distortion. On the other hand, selection of very low current is known to cause lack of penetration & lack of fusion and unstable arc.

3.4.2. Welding voltage –

Welding voltage has marginal affect on the melting rate of the electrode. Welding voltage commonly used in SAW ranges from 20-35 V. Selection of too high welding voltage (more arc length) leads to wider weld bead, higher flux consumption conditions while low welding voltage produces narrow & peaked bead and poor slag detachability.

3.4.3. Welding speed –

Required bead geometry and penetration in a weld joint are obtained only with an optimum speed of welding arc during SAW. Selection of a speed higher than optimum one reduces heat input per unit length which in turn results in low deposition rate of weld metal, decreased weld reinforcement and shallow penetration (Fig.2). Further, too high welding speed increases tendency for a) undercut in weld owing to reduced heat input, b) arc blow due to higher relative movement of arc with respect to ambient gases and c) porosity as air pocket are entrapped due to rapid solidification of the weld metal. On other hand low welding speed increases heat input per unit length which in turn may lead to increased tendency of melt through and reduction in tendency for development of porosity and slag inclusion.

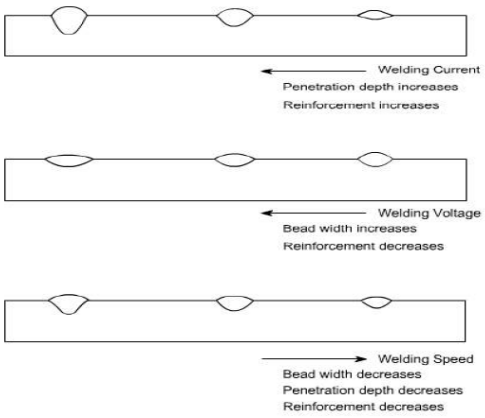

FIGURE.2. INFLUENCE OF WELDING PARAMETERS ON WELD BEAD GEOMETRY.

3.4.4. Bead geometry and effect of welding parameters-

Bead geometry and depth of penetration are two important characteristics of the weld bead that are influenced by size of the electrode for a given welding current setting. In general, an increase in size of the electrode decreases the depth of penetration and increases width of weld bead for a given welding current (Fig.3). Large diameter electrodes are primarily selected to take two advantages a) higher deposition rate owing to their higher current carrying capacity and b) good gap bridging capability under poor fit-up conditions of the plates to be welded due to wider weld bead.

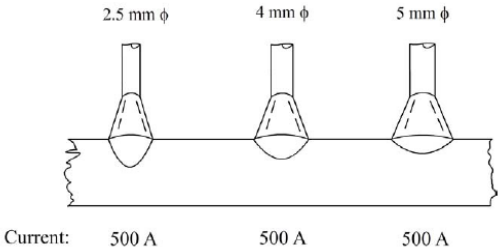

FIGURE.3. INFLUENCE OF ELECTRODE DIAMETER ON WELD BEAD GEOMETRY

IV. ADVANTAGE AND LIMITATIONS

Due to unique features like welding arc submerged under flux and use of high welding current associated with submerged arc welding processes compared with other welding process, it offers following important advantages:

- High productivity due to high deposition rate of the welding metal and capability weld continuously without interruptions as electrode is fed from spool, and the process works under 100% duty cycle.
- High depth of penetration allows welding of thick sections
- Smooth weld bead is produced without stresses raisers as SAW is carried out without sparks, smoke and spatter Limitations

There are three main limitations of SAW a) invisibility of welding arc during welding, b) difficulty in maintaining the flux cover around the arc in odd positions of welding and cylindrical components of small diameter and c) increased tendency of melt through when welding thin sheet. It has became mandatory to use an automatic device (like welding tractors) for accurate and guided movement of the welding arc in line with weld groove so that weld metal is deposited correctly along weld line only. Plates of thickness less than 5 mm are generally not welded due to risk of burn through.

Further, SAW process is known as high heat input process. High heat input however is not considered good for welding of many steels as it leads to significant grain growth in weld and HAZ owing to low cooling rate experienced by them during welding. SAW weld joints are sometime normalized to refine the grain structure and enhanced the mechanical properties so as to reduce the adverse effect of high input of SAW process on mechanical properties of the weld joints.

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