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EFFECT OF ARC WELDING PARAMETERS CONTROLLING SUBMERGED ARC WELDING (SAW) PROCESS- A REVIEW

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Abstract

Submerged arc welding (SAW) is an important metal fabrication technology specially applied to join metals of large thickness in welding process. The process use of granular flux blanket that covers the molten weld pool during operation, protection through atmospheric contamination of the weld bead and slower cooling rate, achieved by this arrangement can improve mechanical properties of the weldment. Welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be assessed in terms of properties such as weld-bead geometry, mechanical properties, and distortion. Best quality and cost effective welds can be achieved by proper understanding the weld metal properties and the influence of welding parameters. This paper presents the comprehensive research review on effect of arc welding parameter on quality of welds.

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INTRODUCTION

Welding is an efficient and economical method for joining of metals. The advantages of welding, as a joining process, include high joint efficiency, good set up, flexibility and low fabrication costs. Due to its good reliability, deep penetration, smooth finish and high productivity, submerged arc welding (SAW) has become a natural choice in industries for fabrication. It is widely recognized as very productive welding process from single wire approach to more productive variants as twin wire, tandem ad metal power addition [1,2]. Due to these qualities SAW is preferred in fabrication Industries. Electrode stick out important parameter in SAW direct effect on parameters like penetration, hardness, impact value, yield strength and ultimate strength of the weld joint [23]. Figure 1. Shows submerged arc welding.

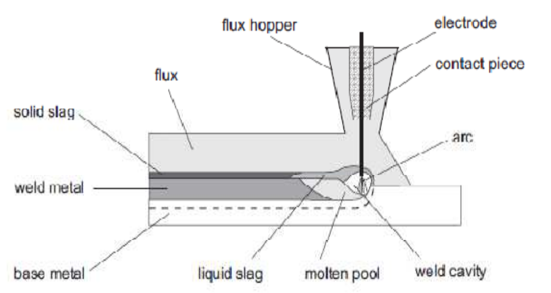

Figure 1 Submerged arc welding

Submerged Arc Welding Process Parameters

A. Arc voltage

Arc voltage, also called welding voltage, means the electrical potential difference between the electrode wire tip and the surface of the molten weld puddle. It is indicated by the voltmeter provided on the equipment. It hardly affects the electrode melting rate, but it determines the profile and surface appearance of the weld bead. As arc voltage increases, the weld bead becomes wider and flatter, and the penetration decreases. Murugun et al.[5] observed that voltage has no significant effect on penetration, reinforcement decreases but bead width increases with increases in voltage. Increase in voltage increases bead width while using a particular electrode diameter and extension irrespective of the electrode positive or negative polarity as shown in Figure 2 [25].

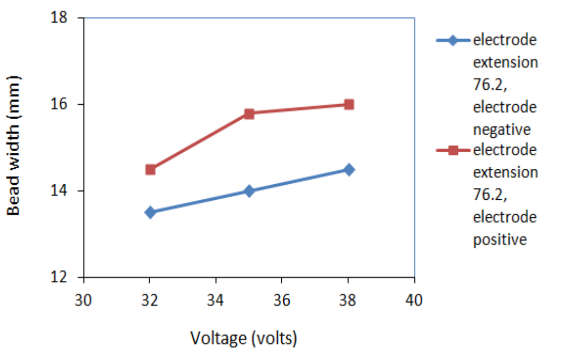

Figure 2 Effect of arc voltage on bead width (after [25])

B. Speed of arc travel

For a given combination of welding current and voltage, increase in the welding speed or the speed of arc travel results in lesser penetration, lesser weld reinforcement and lower heat input per unit length of weld. Excessively high travel speeds decrease fusion between the weld deposit and the parent metal, and increase tendencies for undercut, arc blow, porosity and irregular bead shape. As the travel speed is decreased, penetration and weld reinforcement increase. But too slow a speed results in poor penetration, because under this condition, the weld puddle is directly under the electrode tip and the force of the arc is cushioned by the weld puddle. Excessively slow speeds also produce a convex bead shape, which results in an uneven weld bead with slag inclusions [24]. It is clear from the Figure 3 that with increase in welding speed the bead width increases initially but it decreases with further increase in the welding speed.

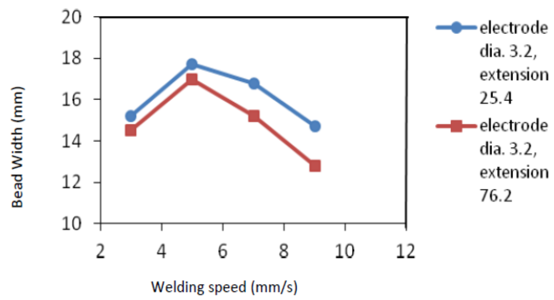

Figure 3 Effect of welding speed on bead width (after [25])

C. Size of electrode

As in the case of SAW, the electrode size is selected according to the plate thickness and the desired size of weld. With increase in electrode size, welding current can be increased so as to get higher deposition rates, deeper penetration and increased weld size. At a given welding current, changing over to a larger electrode results in a wider, less penetrating bead. Hence in joints with poor fit-up, a larger electrode is preferred to a smaller one for bridging the root gap. For a given electrode size, a high current density (i.e. welding current in amps divided by the cross-section of the wire, expressed in amps/ mm^2) results in a strong, penetrating arc, while a lower current density gives a soft arc which is less penetrating [2].

D. Electrode stick-out

It is also termed electrode extension. It refers to the length of the electrode, between the end of contact tube and the arc, which is subject to resistance heating (also called I^2R heating) at the high current densities used in the process. The longer the stick-out, the greater the amount of heating and the higher the deposition rate. Increased electrode stick-out reduces to some extent the energy supplied to the arc, resulting in lower arc voltage and a different bead shape. Hence when the electrode stick-out is increased to obtain higher deposition rate, the voltage setting on the equipment must be increased to maintain correct arc length. Deposition rates can be increased by as much as *25-50%* by increasing electrode stick-out, but the technique is little used in industry. Figure 4(a-d) It shows that with increase in electode stick out hardness of the weldement increases, yield strength and impact value decreases, ultimate tensile strength of the joint initially decreases but after increases provided welding current and voltage are kept at constant [23].

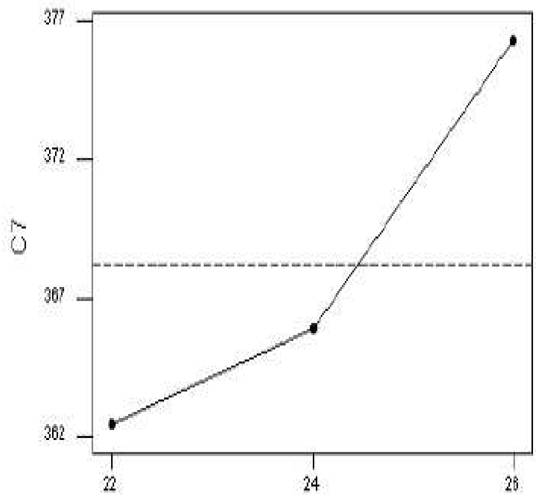

Figure 4 a Direct Effect of Stick out (C2) on Hardness of Weldment (C7)

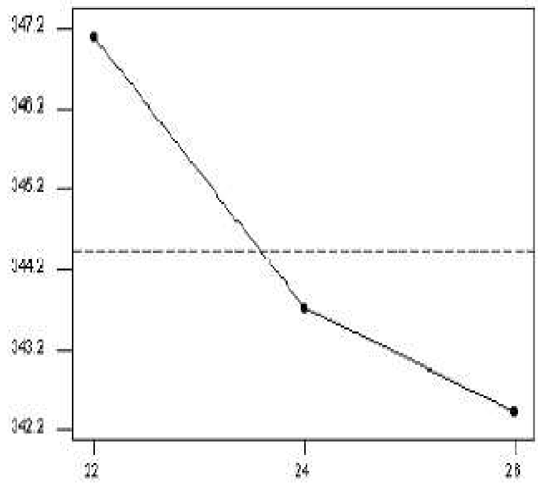

Figure 4 b Direct Effect of Stick Out (C2) Yield Strength of the Joint (C9)

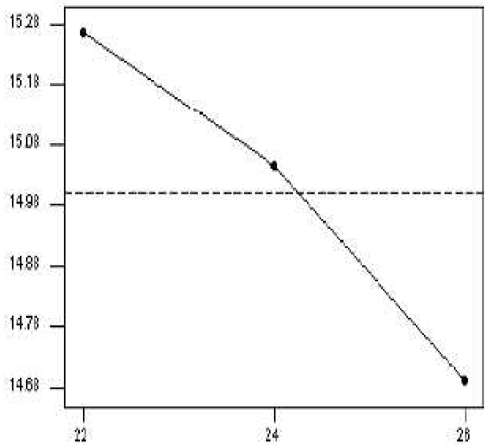

Figure 4 c Direct Effect of Stick out (C2) on Impact Strength of the Joint (C8)

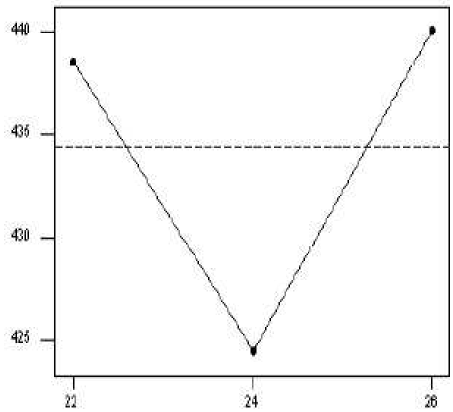

Figure 4 d Direct Effect of Stick out (C2) on Ultimate Tensile Strength of the Joint (C10)

E. Flux

A flux protects weld pool from atmospheric contamination and also provides alloying elements brings about desirable chemical changes to the weld metal and control the shape of the deposited metal. It also pointed out that filler wire and flux composition has a decisive role in formation of weld microstructure to achieve the desired properties in the weldment[10]. Mechanical properties of the welds are improved for the fluxes containing TiO2 contents due to presence of acicular ferrite[11]. Figure 8 shows that with increases in titanium content hardness increase which results in better mechanical properties[12].

F. Welding Polarity

Polarity is the direction of current flow.[13] reported that polarity influences the amount of heat generated at the welding wire and work piece in the welding process which depends on direct current electrode positive (DCEP or reverse) or direct current negative polarity (DCEN or straight). There is more arc spread in straight polarity than in reverse polarity resulting in a higher bead width and less penetration. The two third of the total heat is generated at the positive welding wire and the one third of the total heat is generated at the negative welding wire[14]. Robinson[15] observed that DCEN has more electrode melting rate as compared to DCEP.

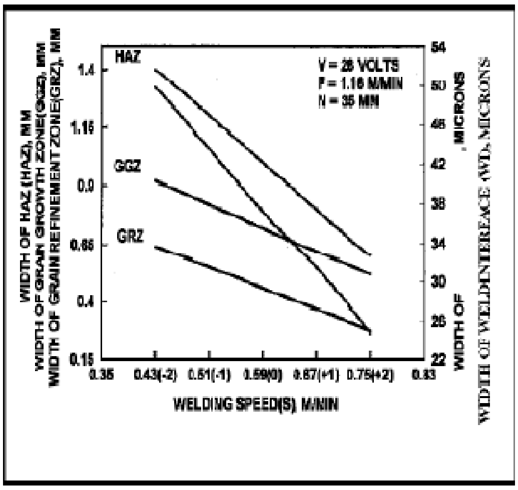

Figure 5 a Direct effect of welding speed on the width of the different HAZ region [26]

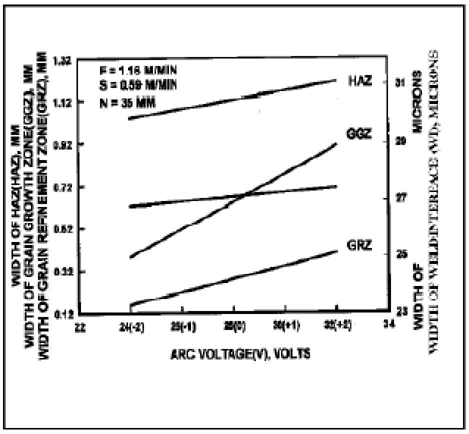

Figure 5 b Direct effect of arc voltage on the width of the different HAZ region [26]

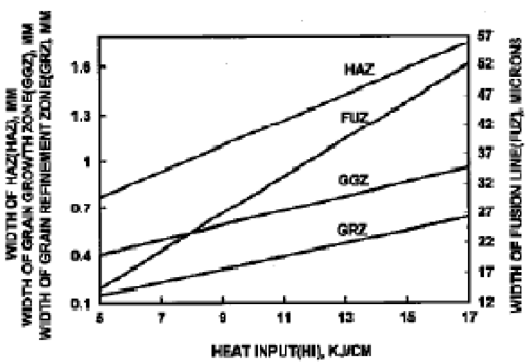

Figure 5 d Direct effect of heat input on the width of the different HAZ region [26]

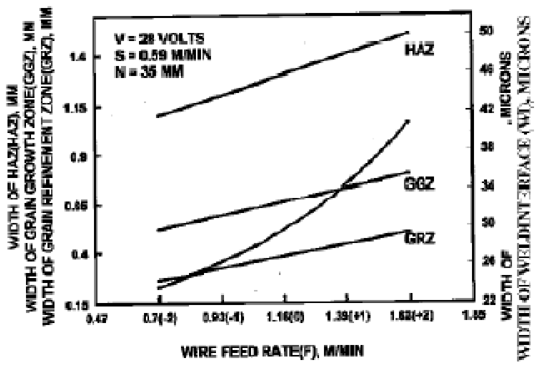

Figure 5 e Direct effect of wire feed rate on HAZ characteristics [26]

REVIEW OF THE QUALITY OF WELD

Submerged arc welding is a welding process which is capable of welding thick material with high productivity and suitable for welding of all sorts of low carbon steel, low alloy steel, stainless steel and heat resisting steels. Review of effect of submerged arc welding on quality of weld joint has been discussed below.

Effect of process parameters on HAZ

In submerged arc welding heat affected zone, required bead size and quality can be controlled by selecting the different process variables.

Viano, D.M.; Ahmed, N.U.; Schumann, G.O. [16], concluded that increase in heat input results in a decrease in cooling rate and the widths of the different zones of the HAZ increase steadily with the increase in heat input. Due to the influence of heat input and travel speed on microstructure and mechanical properties of double tandem submerged arc high strength low alloy steel.

Murugun and Gunaraj [24] while predicting area of heat affected zone for bead on plate and bead on joint in submerged arc welding of pipes developed the mathematical model which can effectively control the area of HAZ by substituting appropriate values of process variables.

V. Gunaraj and N. Murugan [26] Figure 5(a-d). shows the effects of process variables on HAZ parameters. The dimensions of the different HAZ layers increases with the increases in Voltage, wire feed rate, heat input but decreases with increases in welding speed.

Moeinifar, S.; Kokabi, A.H.; Hosseni, H.R.M. [18] on studying the effect of process parameters of tandem submerged arc welding on heat affected zone of welded specimen of high strength low alloy steel found that thermal cycles of tandem submerged arc welding has a significant effect on morphology of martensite and austenite constituents. Investigation of microstructure of submerged arc welded high strength low alloy steel joints revealed that increase in heat input coarsened the grain structures both in weld metal and heat affected zone.

Keshav Prasad; D. K. Dwivedi [17], describe the microstructure and tensile properties of Submerged Arc Welded 1.25Cr-0.5Mo Steel Joints concluded that the increase in the heat input affects the proportions of different micro constituents both in the weld metal and heat affected zone (HAZ). It is also observed that with increase in heat input the tensile strength (UTS, YS) decreases.

Aniruddha Ghosh, Somnath Chattopadhyaya, R.K.Das, P.K.Sarkar [19] describes the Heat Affected Zone related to submerged arc welding process is significantly less. The grain growth are even lower than the 10% of the total area as observed by digital image processing tool and that justifies the low level of heat affected zone of the process. The grains are predominantly of smaller variety and the counts for larger grain are almost negligible. The absence of larger size grains in the image vouch for the soundness of the weld in comparison to the competing welding methodologies of structural steel plates.

EFFECT OF PROCESS PARAMETERS ON MECHANICAL PROPERTIES

The independent process parameters which influence the mechanical properties and can be controlled are voltage, current, stick out, wire feed rate and travel speed, etc. [23].

Prasanta Kanjilal; Tapan Kumar Pal ;Sujit Kumar Majumdar[06], studying the prediction of mechanical properties in submerged arc weld metal of C-Mn Steel, the prediction model has been developed for steel weld metal mechanical properties 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.

A Sharma, N Arora, B K Mishra [9] while the study of statistical modeling of deposition rate in twin-wire submerged arc welding concluded that a significant amount of material loss might occur in the case of single- wire SAW. Material losses also depend on the polarity. In the case of Direct current electrode negative (DCEN), the loss is, on average, about 8 percent, whereas in the case of DCEP, the same is about 4 per cent.

S. W. Wen, P. Hilton and D. C. J. Farrugia [7], 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. It is therefore demonstrated that finite element analysis can be applied to better understand the SAW process and hence will be a useful tool for future process development and control with the view of optimizing product properties.

Kolhe and Datta[20] while the detailed study on the microstructure and mechanical properties of submerged arc weld multipass joint found that welding heat input can control the percentage of phase formation in the welded joint which influences the microstructure. Microstructure and wear property while the study of alloy cladding by submerged arc welding revealed that presence of increased content of retained austenite in the microstructure results in lower hardness.

S. Moeinifar, A.H. Kokabi, H.R. Madaah Hosseini [21] The influence of thermal cycles on the properties of the coarse grained heat affected zone is investigated. The thermal simulated involved heating the X80 steel specimens to the peak temperature of 1400 ◦C, with different cooling rates. The four-wire tandem submerged arc welding process, with different heat input values, was used to generate a welded microstructure. The martensite/ austenite constituent appeared in the microstructure of the heat affected zone region for all the specimens along the prior-austenite grain boundaries and between the bainitic ferrite laths. The blockylike and stringer martensite/austenite morphology were observed in the heat affected zone region. The fractional area of M/A particles due to different cooling rate was the main factor in increasing of the hardness values in the coarse grained heat affected zone. The Charpy absorbed energy of specimens was assessed using Charpy impact testing at −50 ◦C. The martensite/austenite constituent's size such as mean diameter and length are important factors influencing Charpy impact properties of coarse grained heat affected zone. The micro crack nucleation may occur from M/A particles at the intersection of prioraustenite grain boundaries.

EFFECT OF PROCESS PARAMETERS ON WELD BEAD GEOMETRY

Ghosh, A.; Chattopadhyaya, S.; Sarkar, P.K.[22] investigated that weld bead geometry is appreciably affected by input parameters. It shows that increase of welding speed has a negative effect on weld bead parameters and with increase in the current increase in penetration and marginal increase in reinforcement height is observed but the bead width decreased, however increase in arc voltage made the weld bead wider and flatter but decreases the penetration. Wire feed rate has a significant positive effect but welding speed has an appreciable negative effect on most important bead parameter penetration whereas arc voltage has a less significant negative effect on penetration and reinforcement which indicate that weld bead geometry is influenced by these process parameters.

N. Murugan, R.S. Parmar and S.K. Sud [05], while discussing the effect of submerged arc process variables on dilution and bead geometry in single wire surfacing said that the control parameters are required to be feed to the system according to some mathematical formulation to achieve the desired end results. The responses, namely, penetration, reinforcement, width and dilution as affected by open-circuit voltage, wire feed-rate, welding speed and nozzle to plate distance, have been investigated. The main and interaction effect of the control factors is shown in graphical form, which is more useful in selecting the process parameters to achieve the desired quality of the overlay.

R.S. Chandel, H.P. Seow, F.L. Cheong [02] studied the effect of increasing deposition rate on the bead geometry of submerged arc welds concluded that for a given current (and heat input) the melting rate can be increased by using electrode negative, longer electrode extension, and smaller diameter electrodes. There are other ways to increase the deposition rate without increasing the heat input, these being by using a twin-arc mode and by adding metal powders.

J.Tusek, M. Suban[01] It was found that the use of metal powder will increase the deposition rate and the welding arc efficiency and reduce the shielding-flux consumption. When dealing with, high-productivity multiple-wire submerged-arc welding and cladding with metal-powder addition. By using the metal-powder addition it is possible to alloy a weld or a cladding with optional chemical elements.

K. Y. Benyounis, A. G. Olabi[03] while dealing with optimization of different welding processes using statistical and numerical approaches, developed a mathematical relationship between the welding process input parameters and the output variables of the weld joint in order to determine the welding input parameters that lead to the desired weld quality.

Serdar Karaoğlu and Abdullah Seçgin[04] It focuses on the sensitivity analysis of parameters and fine tuning requirements of the parameters for optimum weld bead geometry. Effects of welding current, welding voltage and welding speed design parameters on the bead width and bead height show that even small changes in these parameters play an important role in the quality of welding operation. The results also reveal that the penetration is almost non-sensitive to the variations in voltage and speed.

DISCUSSION

The several process control parameters in SAW influence bead geometry, microstructure of welded joints. Composition of base metal, electrode wire and flux also effect on the microstructure of weld metal. The effect is reflected on the mechanical properties of the weld in terms of weld quality as well as joint performance. The study of various works, reviewed that, the selection of the suitable process parameters are the primary means by which acceptable HAZ properties, optimized bead geometry and minimum residual stresses are produced. Some researchers realized that the mechanical properties of weld are influenced by the composition of the base metal and to a large extent by the weld bead geometry and shape relationship as well. Some of the researchers observed that with increase in electrode stick out, hardness of the weldment increases, yield strength and impact value decreases, ultimate tensile strength of the joint initially decreases but thereafter increases provided welding current and voltage are kept at constant levels. While discussing the submerged arc welding with cored wires few researchers summarized that deposition rates with cored wires at the same welding current are between 20 and 30% higher than with the equivalent diameter solid wire. Some researchers studied the function of flux ingredients such as CaO, MgO, CaF2 and Al2O3 in submerged arc welding and concluded that among the flux ingredients, MgO appears to be important on its own in influencing the mechanical properties. Statistical and numerical methods are useful for determination of optimized welding input parameters which lead to desired weld quality. Further process parameters should be chosen so as to achieve the minimum heat affected zone and least residual stresses and distortion. The following gaps in literature review have been discovered.

- Very less work has been reported on metal transfer in SAW, which influences the chemical composition and metallurgy of weld metal, arc stability, weld bead geometry as well as strength of the weld.
- Very less work on current voltage transient study in submerged arc welding has been reported as many characteristics are influence by current voltage.
- The study of effect of polarity change affects the amount of heat generated at welding electrode and work piece. Hence influences the metal deposition rate, weld bead, HAZ and mechanical properties of the weld metal.

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