© 2016 IJSRSET | Volume 2 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Effects of Various Process Parameters by Tensile and Toughness Test on Weld Joint Quality of HSLA Steel during Submerged Arc Welding

Krishan Kant, Lalit Kumar, Kanika Verma, Deepak Rawat

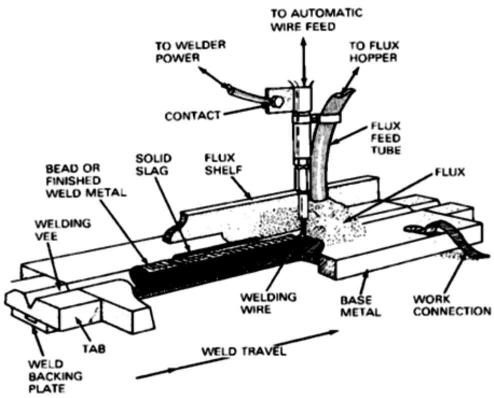
Mechanical Engineering Department, Chandigarh University, Gahuran, Mohali, Punjab, India
Mathematics, Chandigarh University, Gahuran, Mohali, Punjab, India

ABSTRACT

The aim of the present work was to study the effect of various process parameters i.e. current, voltage, travel speed, electrode diameter, flux composition, pre heating of workpiece, electrode stick-out and edge including angle on changes in tensile strength and toughness of the weld bead geometry of HSLA Steel and to optimize the process so that minimal changes occur in the material properties after completion of a submerged arc welding (SAW) process following suitable Taguchi experimental design. Tensile strength of the welded specimens were studied and found that Electrode Diameter, welding current and travel speed were the most significant factors leading to changes in tensile strength. The tensile strength tended to increase significantly with the increase in electrode diameter from 3.2-4 mm. whereas higher tensile strength was observed when welding current 450 Ampere and travel speed 15 m/hr was used. Toughness at room temperature of the welded specimen were studied and found that Electrode diameter, electrode stick-out, current, preheat temperature, voltage and were the most significant factors and higher toughness at room temperature was observed when electrode diameter should be 3.2 mm, electrode stick-out should be 28 mm, welding current should be 350 Ampere, preheat temperature. Toughness at room temperature of the welded specimens were studied and found that type of flux, welding current and electrode stick-out were the most significant factors and higher toughness was observed when welding current 450 Ampere and electrode stick-out should be 28 mm was used. Edge including angle and welding current were found to be the most significant factors leading to changes in toughness. So, it concludes that some compounds of flux goes into the weld region.
Keywords : HSLA, SAW, Taguchi L18 Array, AC.

I. INTRODUCTION

Submerged Arc Welding (SAW) is an arc welding process in which the arc is concealed by a blanket of granular and fusible flux. Heat for SAW is generated by an arc between a bare, solid-metal (or cored) consumable wire or strip electrode and the workpiece. The arc is maintained in a cavity of molten flux or slag, which refines the weld metal and protects it from atmospheric contamination. Alloy ingredients in the flux may be present to enhance the mechanical properties and crack resistance of the weld deposit. the main parts of the machine are control box panel, electrode wire, wire spool and flux hopper.



The welding current, welding voltage and welding speed can be regulated, displayed and preset on the panel of the tractor for the convenience of the operator. The function of inch wire feeding and withdrawing makes it convenient for the welder to preset the operating position of the welding wire. Control is provided on the machine for the movement of the tractor on the platform. The movement can be manual or can be automatic. There is also welding head site adjustment function it make the gun move vertically and horizontally.

II. METHODS AND MATERIAL

A. Principle Of Operation

Continuous electrode is being fed into the joint by mechanically powered drive rolls. Electrical current, which produces the arc, is supplied to the electrode through the contact tube. The current can be direct current (DC) with electrode positive (reverse polarity), with electrode negative (straight polarity), or alternating current (AC). After welding is completed and the weld metal has solidified, the un-fused flux and slag are removed. The un-fused flux may be screened and reused.

1 Set-Up of Saw Process

The typical set-up of SAW consists of

- A wire feeder to drive the electrode to the work through the contact tube of a welding gun or welding head.
- A welding power source to supply electric current to the electrode at the contact tube.
- An arrangement for holding the flux and feeding it ahead of the arc.
- A means to transverse the weld joint.

2 Saw Parameters

While SAW is the most inexpensive and efficient process for making large, long, and repetitive welds, much time and energy are required to prepare the joint. Care must be taken to line up all joints to have a consistent gap in groove welds and to provide backing plates and flux dams to prevent spillage of flux and molten metal. Once all the pieces are clamped or tacked in place, welding procedures and specifications should be consulted before welding begins. Procedural variations in SAW include current, voltage, electrode stick out, travel speed, preheating of workpiece and post-heating of weldment, size of electrode and flux depth and width. Variation in any of these parameters will affect the shape and penetration of the weld, as well as the integrity of the weld deposit.

- **Weld Current**

Welding current controls the parameters such as deposition rate, penetration, and dilution, it is the most important welding variable. An increase in welding current at a constant voltage will decrease the flux-to-wire ratio, while a decrease in current will increase the flux-to-wire ratio. The effect of current variation on weld bead profile Welds made at excessively low current will tend to have little penetration and higher width-to-depth ratios. Welds made at an excessively high current will have deep penetration, high dilution, more shrinkage, and excess build-up. Low current will also produce a less stable arc than higher currents.

- **Travel Speed**

Variations in travel speed at a set current and voltage that affect bead shape. As welding speed is decreased, heat input per length of joint increases, and the penetration and bead width increase. The penetration will increase until molten metal begins to flow under the arc and interfere with heat flow at excessively slow speeds. Excessively high travel speeds will promote a crowned bead as well as the tendency for undercut and porosity.

- **Weld Voltage**

Like current, welding voltage will affect the bead shape and the weld deposit composition. Increasing the arc voltage at a constant current will increase the flux-to-wire electrode ratio, while decreasing the voltage will reduce the flux-to-electrode ratio. The effect of the magnitude of arc voltage on bead .Increasing the arc voltage will produce a longer arc length and a correspondingly wider, flatter bead with less penetration. Higher voltage will increase flux consumption and also produce a hat-shaped concave weld, which has low resistance to cracking and a tendency to undercut. Lower voltages will shorten the arc length and increase penetration. Excessively low voltage will produce an unstable arc and a crowned bead, which has an uneven contour where it meets the plate.

- **Electrode Stick-out**

Electrode stick-out refers to the length of the electrode, between the end of contact tube and the arc, which is subject to resistance 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.

- **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.

B. FLUX

Flux is a chemical cleaning agent which facilitates welding by removing oxidation from the metals to be joined. Common fluxes are: ammonium chloride, rosin, hydrochloric acid, zinc chloride, borax. Different fluxes, based on sodium chloride, potassium chloride, sodium fluoride are used. In high-temperature metal joining processes (welding, brazing and soldering), the primary purpose of flux is to prevent oxidation of the base and filler materials. Tin-lead solder attaches very well to copper, but poorly to the various oxides of copper, which form quickly at soldering temperatures. Flux is a substance which is nearly inert at room temperature, but which becomes strongly reducing at elevated temperatures, preventing the formation of metal oxides. Flux is normally used in granular form and a sample stock of flux.

The functions of the flux are:

To assist arc striking and stability.

- To form a slag that will protect and shape the weld bead.
- To form a gas shield to protect the molten filler metal being projected across the arc gap.
- To react with the weld pool to provide clean high quality weld metal with the desired properties.
- To deoxidise the weld pool.
- Provide de-oxidants.

C. Sources of Defects In Saw

The fact that SAW is a high heat input process under a protective blanket of flux greatly decreases the chance of weld defects. However, defects such as lack of fusion, slag entrapment, solidification cracking, hydrogen cracking, or porosity occasionally occur.

1. Insufficient Fusion and Slag Entrapment

Lack-of-fusion defects and slag entrapment are most commonly caused by improper bead placement or procedure. Improper placement can cause the weld metal to roll over and trap slag underneath, or if the weld bead is placed away from the edge to be joined, the liquid metal may not fuse to the base material. A crown-shaped bead caused by low welding voltage may also contribute to slag entrapment and lack of fusion by not allowing the liquid metal to spread out evenly.

2. Solidification Cracking

Solidification cracking of saw along the centre of the bead is usually due to bead shape, joint design, or incorrect choice of welding consumables. A convex bead shape with a bead widthto- depth ratio greater than one will decrease solidification cracking tendencies. If weld penetration is too deep, the shrinkage stresses may cause centreline cracking. Joint design may also contribute to excessive shrinkage stresses, again increasing the risk of solidification cracking.

Because cracking is related to stresses in the weld, high-strength materials will have a greater tendency to crack. Therefore, special care must be taken to generate proper bead shape, preheat temperatures, and interpass temperatures, in addition to correct electrode and flux combinations, when welding these materials.

3. Hydrogen Cracking

Unlike solidification cracking, which appears immediately after welding, hydrogen cracking is a delayed process and may occur from several hours to several days after welding has been completed. To minimize hydrogen cracking, all possible sources of hydrogen (for example, water, oil, grease, and dirt) present in the flux, electrode, or joint should be eliminated. The flux, electrode, and plate should be clean and dry. To prevent moisture pickup, fluxes and electrodes should be stored in moisture resistant containers in dry areas. If a flux or electrode becomes contaminated with moisture, it should be dried according to manufacturer recommendations. To further reduce hydrogen related cracking, the joint to be welded should be preheated. Because hydrogen is fairly mobile in steel at temperatures above 95°C, the recommended preheat temperatures should be followed to allow most of the hydrogen to escape and to reduce the risk of hydrogen damage. In thick weldments, maintaining preheat for several hours after welding is completed, will also reduce the risk of hydrogen cracking.

4. Porosity

Porosity caused by trapped gas is uncommon in SAW because of the protection provided by the flux. When porosity does occur, it may be in the form of internal porosity or as depressions on the weld bead surface. The gas bubbles that cause porosity originate either from a lack of protection from the atmosphere or from contaminants such as water, oil, grease, and dirt. To reduce porosity in SAW, the weld should have sufficient flux coverage, and all water, grease, and dirt should be removed from the plate, electrode, and flux. Another cause of porosity in SAW is excessive travel speed. Travel at excessively high speeds will not allow the gas bubbles to escape from the weld, and the bubbles may become trapped in the weld metal at the slag-to-metal interface.

D. High Strength Low Alloy Steel

High Strength Low Alloy (HSLA) Steel is a type of alloy steel that provides better mechanical properties or greater resistance to corrosion than carbon steel. HSLA steels vary from other steels in that they aren't made to meet a specific chemical composition, but rather to specific mechanical properties. They have carbon content between 0.05–0.25% to retain formability and weldability. Other alloying elements include up to 2.0% manganese and small quantities of silicon, sulphur, phosphorous, copper, nickel, niobium, vanadium, chromium, molybdenum, titanium, calcium, rare earth elements, or zirconium. Copper, titanium, vanadium, and niobium are added for strengthening purposes. These elements are intended to alter the microstructure of carbon steels, which is usually a ferritepearlite aggregate, to produce a very fine dispersion of alloy carbides in an almost pure ferrite matrix. This eliminates the toughness-reducing effect of a pearlitic volume fraction, yet maintains and increases the material's strength by refining the grain size, which in the case of ferrite increases yield strength. The yield strengths vary between 250–655 MPa. Due to their higher strength and toughness HSLA steels usually require 25 to 30% more power to form, as compared to carbon steels. Copper, silicon, nickel, chromium, and phosphorus are added to increase corrosion resistance. Zirconium, calcium, and rare earth elements are added for sulphide-inclusion shape control which increases formability. These are needed because most HSLA steels have directionally sensitive properties. Formability and impact strength can vary significantly when tested longitudinally and transversely to the grain. HSLA steels are also more resistant to rust than most carbon steels, due to their lack of pearlite – the fine layers of ferrite.

E. Objective of The Study

The objective of this study is to evaluate the effects of welding parameters such as welding voltage, current, travel speed, different flux compositions, electrode stick-out, edge preparation, pre-heating of work piece and filler wire diameter on tensile strength, impact Strength and toughness of the weld metal of HSLA work piece and the results are analysed by optimization of the process parameters. None of the study reported in the literature comprehensively cover all the welding parameters for HSLA material greater than 28 mm thickness.

F. Design of Experimental Study

The literature review showed that any change in the parameter of submerged arc welding affect the properties of welding. So, in this study it was proposed to find out the effect of changing different welding parameters on tensile strength, toughness. The high strength low alloy plate of dimension 140 x 125 x 28 mm was used as a work material. The experiments have been conducted on Submerged Arc Welding Machine i.e. Tornado Saw M-800 transformer and FD 10-200T welding tractor available at Maharashi Markendeshwar University, Mullana

The main parts of the machine are control box panel, electrode wire, wire spool and flux hopper. The welding current, welding voltage and welding speed can be regulated, displayed and preset on the panel of the tractor for the convenience of the operator. The function of inch wire feeding and withdrawing makes it convenient for the welder to preset the operating position of the welding wire. Control is provided on the machine for the movement of the tractor on the platform. The movement can be manual or can be automatic. There is also welding head site adjustment function it make the gun move horizontally and vertically.

Sr. No	Parameters	Units	Mim	Max
1	Welding Current	A	350	450
2	Voltage	V	28	32
3	Arc Speed	m/hr	15	20
4	Electrode tip	Mm	20	35
5	Edge angle	Degree	60	90
6	Preheating	^{o}C	100	150
7	Electrode Diameter	mm	3.2	4

Table 1. Process parameters & their level

III. RESULTS AND DISCUSSION

A. Experimental Set Up

As stated earlier Taguchi L18 array has been selected for the experimentation. The experimental design was completed using the Taguchi's fractional factorial experiments (FFEs). Welding current, Voltage, Speed of arc travel, Electrode stick-out, Edge including angle, Pre heating of workpiece, Different flux composition and Electrode diameter have been chosen as the factors of interest. L18 array with actual factors level is shown in Table 2:

Exp. No.	Electrode Diameter 'O' (mm)	Current 'C' (Amp)	Voltage 'V' (Volt)	Electrode Stick-Out 'D' (mm)	Travel Speed 'S' (m/hr)	Preheat Temperature 'T' (°C)	Flux 'F'	Edge Including Angle 'a' (degree)
1	3.2	350	28	20	15	No Preheat	1	60
2	3.2	350	30	28	18	100	2	75
3	3.2	350	32	35	20	150	3	90
4	3.2	400	28	20	18	100	3	90
5	3.2	400	30	28	20	150	1	60
6	3.2	400	32	35	15	No Preheat	2	75
7	3.2	450	28	28	15	150	2	90
8	3.2	450	30	35	18	No Preheat	3	60
9	3.2	450	32	20	20	100	1	75
10	4	350	28	35	20	100	2	60
11	4	350	30	20	15	150	3	75
12	4	350	32	28	18	No Preheat	1	90
13	4	400	28	28	20	No Preheat	3	75
14	4	400	30	35	15	100	1	90
15	4	400	32	20	18	150	2	60
16	4	450	28	35	18	150	1	75
17	4	450	30	20	20	No Preheat	2	90
18	4	450	32	28	15	100	3	60

B. Cutting Of Steel Plates

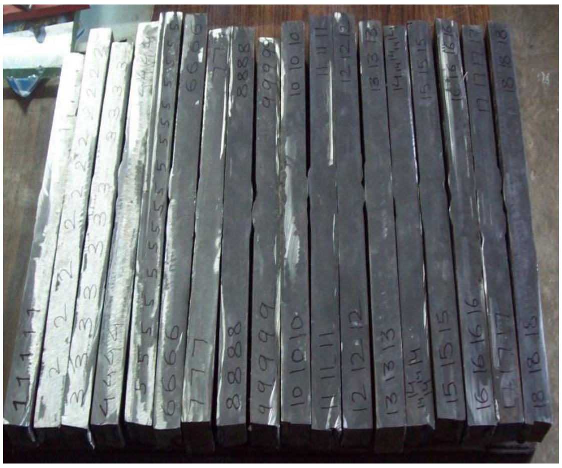
The steel plates available for the study were of size 1000 x 500 x 28 mm. These were firstly cut in to strip of size 1000 x 125 x 28 mm through oxy-acetylene gas cutting as shown in Figure.Then these steel strips were cut to the required size of 140 x 125 x 28 mm with the help of power hacksaw.

After cutting these plates we just joined through the SAW weldings and then applying various testing methods for justifying the tensile and toughness test.

C. Testing of Weld Specimen

- **Tensile Test**

Ratio of the maximum load a material can support without fracture when being stretched to the original area of a cross section of the material. When stresses less than the tensile strength are removed, a material completely or partially returns to its original size and shape. As the stress approaches that of the tensile strength, a material that has begun to flow forms a narrow, constricted region that is easily fractured. Tensile strengths are measured in units of force per unit area. Welded specimen made from base metal and fined the tensile strength and stress-strain curves.



The testing would be carried on Computerised Universal Testing Machine the schematic of tensile test specimen and the specimens before machining and the machining was done on lathe after that the tensile test specimen.

- **Toughness Test**

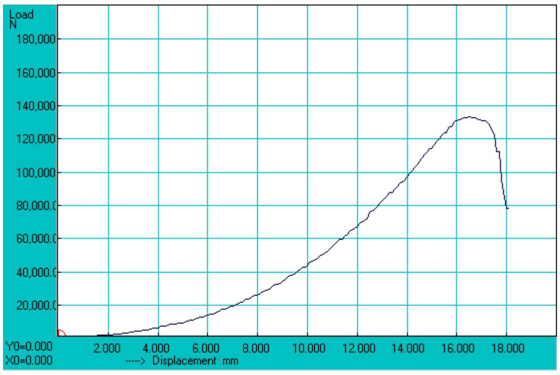
The ability of a metal to rapidly distribute within itself due to both the stress and strain caused by a suddenly applied load or the ability of a material to withstand shock loading. It is the exact opposite of "brittleness" which carries the implication of sudden failure. A brittle material has little resistance to failure once the elastic limit has been reached. The weld region specimen which is of dimension 60 X 90 X 28 mm and the removal of material from both sides of specimen take place on vertical milling machine then cutting of specimens for testing purpose which was to be cut on surface grinding machine. According to standard cutting specimen were made from each plate of size 10x10x55 mm for charpy test as shown in Figure and test all the specimen on charpy toughness test machine as shown Figure at different temperatures by applying liquid nitrogen i.e. room temperature (37 oC),

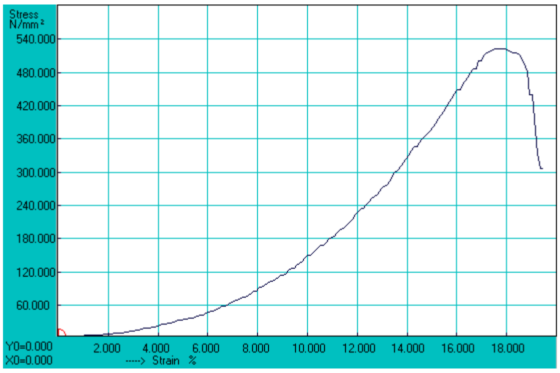
D. Results and Analysis of Tensile Test:

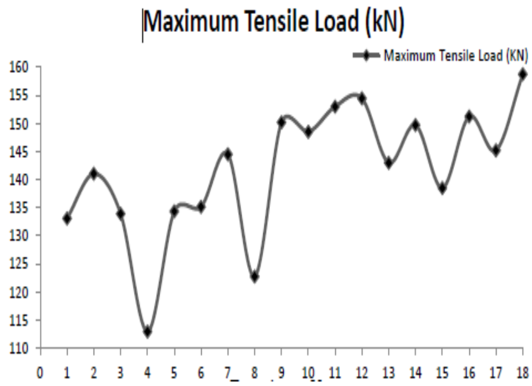
Tensile Test

Ratio of the maximum load a material can support without fracture when being stretched to the original area of a cross section of the material. Specimen after tensile test is shown in Figure

Base Metal	Maximum Load (kN)	Maximum Tensile Strength(N/mm2)
HSLA	159.9	685.4



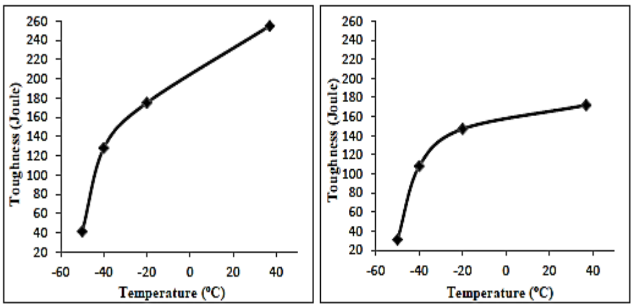




Toughness Test

The ability of a metal to rapidly distribute within itself due to both the stress and strain caused by a suddenly applied load or the ability of a material to withstand shock loading. It is the exact opposite of "brittleness" which carries the implication of sudden failure.

Base Metal	Toughness	Charpy Test at Room Temperature (J)
HSLA	20-250	218



IV. CONCLUSION

The present study was carried out to study the effect of process parameters on weld joint quality during submerged arc welding of HSLA steel. The process parameters that has been considered for changing are current, voltage, travel speed, electrode diameter, flux composition, pre heating of workpiece, electrode stick-out and angle of edge preparation were varied at different levels. The following conclusions have been drawn from the study :

- Welding current was found to be the most significant factor that affects the tensile strength and toughness.
- The flux composition did not show any significant affect on tensile strength, but had a major effect on impact strength and toughness.
- Tensile strength is majorly affected by electrode diameter, but did not show any significant effect on toughness.
- Travel speed did not show any significant effect on toughness, but had a major effect on tensile strength.
- Voltage has no significant effect on tensile strength, but has a little affect on toughness at room temperature.
- Edge including angle did not show any significant affect on tensile strength and toughness.

V. REFERENCES

[1] Krishankant, Sandeep Jindal, Shashi Kant Shekhar Submitted a research paper entitled, "Determination of Flux Consumption in submerged arc welding by the effect of welding Parameters by using R.S.M Techniques, "Global Journals of Researches in Engineering, Feb.2012. Volume 12 Issue 2.ISSN 0975-5861.Jonathan S. Ogborn, the Lincoln Electric Company, "Welding, Brazing and Soldering", ASM Handbook, Volume-6, pp. 618-641, ISBN 0-87170-377-7(V.1), 1993.

[2] Beidokhti, A.H. Koukabi, A. Dolati, "Effect of titanium addition on the microstructure and inclusion formation in submerged arc welded HSLA pipeline steel." Journal of Materials Processing Technology, Volume 209, pp. 4027–4035, 2009.

[3] Krishankant, Mohit Bector, et.al , "Application of Response Surface Modeling for determination of Flux consumption in submerged arc welding by the effects of various welding parameters ,"International Journal of Mechaninal Engineering & Robotics Research, Oct .2012. Vol. 1, No. 3, © 2012 IJMERR. ISSN 2278 – 0149 .

[4] S.D. Bhole, J.B. Nemade, L. Collins, Cheng Liu, "Effect of nickel and molybdenum additions on weld metal toughness in a submerged arc welded HSLA line-pipe steel". Journal of Materials Processing Technology, Volume 173, pp. 92–100, 2006.

[5] S. Ravi, V. Balasubramaniana, S. Nemat Nasser, "Influences of post weld heat treatment on fatigue life prediction of strength mis-matched HSLA steel welds". International Journal of Fatigue, Volume 27, pp. 547–553, 2005.

[6] J. Vojvodic Tuma, A. Sedmak, "Analysis of the unstable fracture behaviour of a high strength low alloy steel weldment" Engineering Fracture Mechanics, Volume 71, pp. 1435-1451, 2004.