International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 2, April, 2014

Review Article

STUDIES ON THE EFFECT OF ELECTRODE EXTENSION AND PROCESS PARAMETERS ON DISTORTION BY SUBMERGED ARC WELDING

B E Mallikarjuna[1], Yellappa M[2], Satyamurthy N[3], Giriswamy B G[2] and Puneet U[2]

Corresponding Author: **Yellappa M, ✉ meetyellappa1983@gmail.com*

Welding is a process of permanent joining of two metals through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combinations of the above mentioned, a wide range of welding processes has been developed. Submerged Arc Welding (SAW) is an automatic welding process and is one of the chief metal fabrication process in industries, which involves high current density and effects high metal deposition rates. In SAW, the process parameters like welding current, arc voltage, speed of arc travel, size of electrode, electrode stick-out, heat input rate are to be studied. To get an optimum result, one must know their effects and how to select and control them. The present work is carried out to study the influence imposed by electrode extension, one of the important process parameters of SAW on a major welding defect known as distortion on a commercial use mild steel plate of size 150mm x 200mm x 10mm. The direct interaction effects of electrode stick-out on welding distortion is brought and concluded by graphical plots.

Keywords: Submerged Arc Welding, Electrode, Flux, Arc, Slag, Distortion

INTRODUCTION

Welding is a reliable and efficient joining process in which the coalescence of metals is achieved by fusion and is used extensively in fabrication of many structures, building ships, pressure vessels, etc., due to many advantages it has, over other processes. Localized heating during welding, followed by rapid cooling can generate residual stresses and distortion. However, distortion is a problem encountered during welding.

Nowadays there are numerous types of welding techniques according to the applications required in which the major part of the industries employ SAW. Due to the high quality of weld produced, high metal deposition rate and cost effectiveness, it is more preferred.

The quality of weld in SAW is mainly influenced by independent variables like current, voltage, speed and stick-out. The prediction of process parameters involved in

[1] Lecturer, Mechanical Department, Impact Govt Aided Polytechnic, Bangalore.
[2] Assistant Professor, Mechanical Department, SJBIT, Bangalore-60.
[3] Associate Professor, Mechanical Department, SJBIT, Bangalore-60.

SAW is a very complex process. The influences of weld current, speed and arc voltage on distortion are already studied by researches.

The present work is carried out by experimental methods to find out the amount of distortion due to variable electrode stick-out with constant voltage, speed and current using SAW process. When the electrode stick-out is increased, it results in an increase in electrical resistance. This results in extra heating and an increase in melting rate. But, the energy so consumed reduces power delivered to the arc. This reduces arc voltage even while open circuit voltage is kept constant. This results in a variable degree of angular distortion which can be noted either as a direct effect of electrode stick-out or as a change in current which can be studied experimentally on a commercial use mild steel plate.

SUBMERGED ARC WELDING (SAW)

A. Introduction to SAW

During the 1930s, having recognized the potential advantages of mechanical welding, several attempts were made to mechanize the the arc welding process, developing a continuous coated electrode as an extension of the manual metal arc welding electrode was ruled out.

The modern SAW is an arc welding process, in which one or more arcs formed between one or more bare wire electrodes and the work piece provide the heat for coalescence. The arc is completely submerged under a blanket of granular, fusible flux, which adequately shields the arc. The process can be fully or partially automated.

During welding, the intense heat of the arc simultaneously melts the the of the bare wire electrode and part of the flux. The electrode tip and the welding zone are always surrounded and protected by molten flux, which all of them are covered by the top layer of unfused flux. As the arc progresses along the joint, the molten metal settles down while the lighter flux rises from the puddle in the form of slag. The weld metal, having a higher melting point, solidifies first while the slag above takes time. The solidified slag continuous to protect the weld metal while it is still hot, and is capable of reacting with atmospheric oxygen and nitrogen.

B. Advantages and applications

The process is extensively used in heavy steel plate fabrication, because of the following advantages:

a. Absence of smoke and arc flash
b. High quality metal weld
c. Smooth and uniform weld finish with no splatter
d. Extremely high deposition rates
e. High electrode deposition rates
f. Minimum operation fatigue
g. Wide range of applications.

C. SAW equipment

It essentially consists of:

a. A wire feeder to drive the electrode to work through the contact surface
b. A welding power source to apply electric current to the electrode
c. An arrangement for holding the flux
d. A means of traversing the weld joint.

D. Power source

The welding power source can either be of the following

a. An ac transformer of constant current type
b. A dc generator of the constant voltage/ current type
c. A dc rectifier of the constant voltage/ current type

AC power calls for more elaborate and complicated controls ant the arc starting is not easy. The main advantage is that it minimizes arc blow, which can become troublesome at 900 amps. In SAW with multiple wires and power source, the trailing arc or arcs are derived from ac because 2 dc arc 100mm or less apart arc deflected by each others magnetic field.

Use of power for SAW has the following advantages:

a. Easy and accurate arc start
b. Good control of weld bead profile, depth of penetration and welding speed
c. Difficult contours can be negotiated at high weld speeds

In using dc, electrode positive gives an extremely stable arc and smaller weld puddle, which leads to better control of weld bead profile. The weld penetration is also deeper. Electrode negative gives highest metal deposition rates, but shallower penetration. Penetration with arc is more than that obtained with dc electrode negative, but less ith positive. DC can present the problem of arc blow as stated earlier.

Whether ac or dc, the power source should be rated 100% duty cycle and not 60% as required for manual welding. This is because SAW is a semi-automatic rocess, for which full duty rating is required. This means the power source should be designed to deliver its rated output continuously, without exceeding the prescribed temperature limits of its components. Most SAW is done in the current range of 200 to 1000amps. In rare cases, the current can go up to 4000amps at 55v and be as low as 150amps at 18v. For common applications, it is convenient to have a power source giving a maximum current output of 500 or 1000amps at 100% duty cycle.

E. Arc start

Unlike in manual welding, arc starting can be difficult in SAW, because of the flux cover. There are several methods available and the choice is dictated by the design of the power source, the time required for the starting as compared to the total weld time, the frequency of starts demanded by production and the importance of starting the weld at a specific point on the joint. The methods are:

a. With steel wool or iron powder
b. Sharp wire start
c. Scratch start
d. Molten flux start
e. Wire retract start
f. High frequency start

F. Arc stopping

Normally for terminating the arc, the carriage travel is first stopped, then the wire feed is switched off and a couple of seconds later, the current is switched off. The brief pause prevents the wire from moving forward into the molten pool and from sticking to the molten puddle as it solidifies. It also helps to fill up craters.

PROCESS PARAMETERS

In SAW, the weld deposits quality is determined by the type of flux, grade of wire and the following parameters:

a. Welding current

b. Arc voltage

c. Speed of arc travel

d. Size of the electrode

e. Electrode extension

f. Heat input rate

To get optimum results, one must know their effects and how to select and control them properly.

A. Welding current

It controls the melting rate of the electrode and thereby the weld deposition rate. It also controls the depth of penegtration and thereby the extent of dilution of the weld metal by the base metal. Too high current causes excessive weld reinforcements which is wasteful, and burn through in case of thinner plates or in badly fitted joints, which are not provided with proper backing. Excessive current also produces a high narrow bead and undercut. Excessively low current gives an unstable arc, inadequate penetration and overlapping. SAW equipment is usually provided with an ammeter to monitor and control the weld current.

B. Arc voltage

It is 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 bead. As arc voltage increases, the weld bead becomes wider and flatter, and the penetration decreases, the effects of changing voltage are explained as follows:

a. Produces a flatter and wider bead

b. Increases flux consumption

c. Increases resistance to porosity caused by rust or scale

d. Helps bridge gaps when fit is poor

Lowering the voltage produces a stiffer arc needed for getting penetration in a deep groove and to avoid arc blow on high speed work.

C. 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 reinforcements and lower heat input per unit length of weld, excessively high travel speeds decreases fusion between the weld deposit and the parent metal, and increases tendencies for undercut, arc blow, porosity and irregular bead shape. As the travel speed decreases, penetration and weld reinforcements increases, but too low 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.

D. Size of electrode

As in the case of MMA welding, 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 increase in 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 fits, a large electrode is preffered to a smaller one for bridging the root gap. For a given electrode size, a higher current density results in a strong, penetrating arc, while a lower current density gives a soft arc which is less penetrating.

E. Electrode extension

It is also termed as electrode stick-out. It refers to the length of the electrode, between the end of the contact tube and the arc, which is subject to resistance heating at high current densities used in the process. Longer the stick-out, greater the amount of heating and higher the deposition rates.

The maximum electrode stick out recommended are 75mm for 2.0, 2.4 and 3.2 mm wire diameters, 125mm for 4.0, 4.8 and 5.6 mm wire diameters.

Regarding weld bead shape, reinforcements was found to increase with increased electrode extension. Regarding weld metal properties, increased electrode extension at a constant head voltage and energy results in an increase in yield and tensile strength, but with inconsistent changes in the Charpy behaviour. With constant arc voltages changes in strength were small and inconsistent, and the Charpy transition behaviour detiorated slightly with electrode extension and energy expenditure.

F. Heat input rate

It is also termed as arc energy, it is calculated by using the formula:

HIR=(V*A*60)/(S*1000)

Where

HIR= heat input rate in kilojoules per mm

V= arc voltage

A= welding voltage

S= arc travel speed in mm/min

For a given thickness, the higher heat inputrate, lower is the cooling rate of the weld metal and the heat affected zone of the parent metal, and vice versa. HIR has an important bearing on the weld metal microstructure and the final microstructure of the HAZ, and thereby on their toughness.

SAW FLUXES

A. Introduction to SAW fluxes

SAW fluxes basically perform the same functions as the coating of a manual electrode; additionally, it must satisfy certain conditions demanded by the nature of process.

The flux protects the molten pool and the arc against atmospheric oxygen and nitrogen by creating an envelope of molten slag. The slag also cleanses the weld metal i.e., deoxidizes it and removes impurities such as sulfur, modifies its chemical composition and controls the weld bead profile. Like manual electrode coating, the SA flux can incorporate alloying elements, so that in combination with an unalloyed wire, it will yield suitably alloyed weld metal. The molten slag also provides favorable conditions for very high current densities, which, together with the insulating properties of yhe flux, concentrate intense heat into a relatively small welding zone. This results in a deeply penetrating arc, which makes narrower and shallower welding grooves practicable, thus reducing the amount of weld metal required to complete the joint.

B. Types of fluxes

The main types of SAW fluxes depends on the method of manufacture, and are as follows:

a. Fused fluxes
b. Agglomerated fluxes
c. Sintered fluxes

C. Particle size

Particle size is an important property of SAW flux. During welding, a finer flux produces a more dense and compact burden over the flux cavity, thereby reducing its volume. Evolution and escape of gases from the weld bead then becomes more difficult and thus results in a characteristic aerated slag. Finer fluxes are also less tolerant to oil and rust, because of the inability of the resultant gases to escape. A large increase of particle sub-size in a flux can give rise to a peaky weld bead with increased penetration.

DISTORTION

A. Introduction to distortion

Distortion and residual stresses are two major perennial problems faced by fabrication engineers. The change of shape and dimensions that occur after welding is termed as distortion, leading to variable undesirable consequences. It creates difficulties in maintaining correct shape, dimensions and tolerances of a finished fabrication.

Distortion is caused by unequal heating and cooling of a metallic body during welding. It is also caused by the contraction of weld metal during solidification and cooling to room temperature ant the contraction of the surrounding parent metal as it cools from higher welding temperature. When these portions contract, they try to pull the parts together and the result is distortion.

A metallic body does not distort if it is heated as a whole uniform and is then cooled as a whole uniformly and has a freedom to expand and contract an all directions. In welding, however, only the weld joints and its surrounding area are heated up. This area has no freedom to expand or contract. Uneven contraction of the weld metal and parent metal occurs. This gives rise to stresses in the weld, in the two component parts making up the joint and in the entire fabrication. If the fabrication is held firmly in a jig that gives no freedom of movement, the stresses will remain in the body as locked-up stresses. But, if there is some scope for movement, the stresses will find relief in distortion. Consequently, the shape and dimensions of the welded fabrication will have changed whenit returns to room temperature.

B. Factors responsible for distortion

There are many factors responsible for distortion in the weldment, some of which are:

a. Thickness of plate
b. Welding current
c. Heat input
d. Number of passes

So, there exists a necessity to control distortion within limits. When distortion exceeds an acceptable limit, correction of it after the complete fabrication results in major reworking operation that consumes both fabrication time and cost.

Distortion can often be controlled by adapting a suitable sequence of welding. A correct welding sequence which reduces distortion to a minimum does not remove or lowere the locked-up stresses. It merely distributes them evenly across the whole structure and thereby reduces the risk of cracking.

Types of distortion:

a. Longitudinal shrinkage distortion
b. Transverse shrinkage distortion
c. Angular distortion

CONCLUSION

The experimental studies we carried out on welding distortion on commercial mild steel plates with varying electrode stick-out in controlled manner (from 20 to 40mm) using standard Submerged Arc Welding equipment and recorded the results. By these outcomes, the conclusions derived are:

1) It is concluded that as electrode stick-out increases, there will be a gradual

decrease in distortion

2) It is also concluded that as electrode stick-out increases, the deposition rate is high

3) It is concluded that there will be a very less or negligible variation of longitudinal and transverse shrinkage during the process

4) It is concluded that as the electrode extension increases, there will be a gradual increase in flux consumption

REFERENCES

1. ASME Welding Hand Book, 6th ed., American Welding Society.
2. Howard B Cary, Scott C Helzer, "Modern Welding Technology", *6th ed., Prentice Hall Publications*.
3. Leonard P Connor, "Residual Stresses and Distortions", 6th ed.
4. Robert W M Jr. (1999), "Principles of Welding", J*ohn Wiley & Sons, New York*. pp. 181-194,
5. S V Nadakarni, "Modern Arc Welding Technology", *2nd ed., Oxford and IBH Publications, India*.
6. S Datta and A Bandyopadhyay (2005), "Effects of electrode stick-out on quality and performance of Submerged Arc Weldment" *journal by proceedings of the International Conference on Mechanical Engineering, Dhaka*.
7. S Kumaran and R Gowtham (2007), "Determination of Submerged Arc Welding process parameters using Taguchi method", *Indian Journal of Engineering and Material Sciences*.
8. www.wikipedia.com