ador WELDING

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Submerged Arc Welding:

Parameters and Variables

Introduction:

Submerged arc welding (SAW) is high productivity welding process widely used in heavy structural welding. SAW has high deposition rate with high depth of penetration. It is a continuous welding process without interruptions with the electrode wire being supplied through a wire coil wound on a spool. Welding is carried out without sparks, smoke or spatter. Weld bead is very clean and smooth. Welds produced are of high quality with good mechanical and metallurgical characteristics.

The Bead shape, penetration, slag removal and weld quality of SAW depends on many factors like arc voltage, welding current, travel speed, the way wire speed is controlled and type of welding output of either constant current or constant voltage is used.

This article will dwell upon the effect of parameters and variableson the SAW process and as a result its efficiency.

Submerged Arc Welding Process:

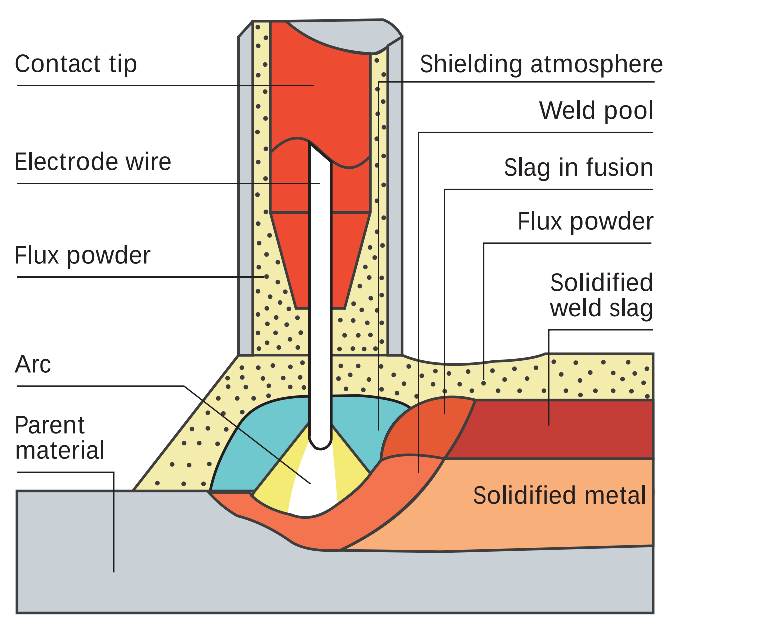
Submerged arc welding is an arc welding process in which the arc and the weld zone are completely covered under a blanket of granular, fusible flux which melts and provides protection to the weld pool from the atmospheric gases.

The molten flux surrounds the arc thus protecting arc from the atmospheric gases. The molten flux reacts with the molten metal forming slag and improves its properties and later floats on the molten/solidifying metal to protect it from atmospheric gas contamination and retards cooling rate. Process of submerged arc welding is illustrated in Figure 1.

Extremely high welding currents can be used without the danger of spatter and atmospheric contamination giving deep penetration with high welding speeds.

A proper selection of flux-wire combination can produce welds of very high quality. This makes the process very suitable for the welding of high strength steel at welding speeds much higher than conventional manual metal arc welding.

A continuous consumable wire electrode is fed from a wire reel through contact tube which is connected to one terminal of power source. Wires in the range 1 - 5 mm diameters are usually used.



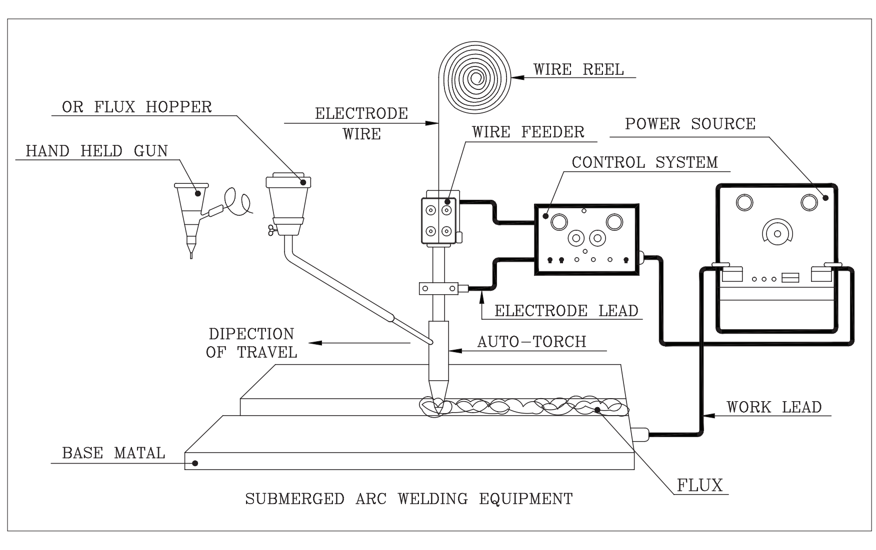
Process of Submerged Arc Welding

Submerged Arc Welding Equipment:

Submerged arc welding (SAW) equipment consists of a welding power source, the wire feeding mechanism with the control system, the welding torch or the welding gun. The assembly is called the welding head and cable assembly for semiautomatic welding. The flux hopper and feeding mechanism, usually a flux recovery system, and a travel mechanism for automatic welding form the entire setup for the SAW process.

Submerged arc welding head may be mounted on self-propelled tractors carrying a flux hopper and the coiled electrode. A suction device may also be carried to recover the unused flux for reuse.

Since the end of the electrode and the welding zone are completely covered at all times during the actual welding operation, the weld is made without the sparks, spatter, smoke or flash commonly observed in other arc welding processes.



Type of Welding Output:

The submerged arc welding process uses either direct or alternating current for welding power. Direct current is used for most applications which use a single arc. Both direct current electrode positive (DCEP) and electrode negative (DCEN) are used. The deposition rate is the highest for direct current electrode negative (DCEN). The deposition rate for alternating current is between DCEP and DCEN. The polarity of maximum heat is the negative pole.

The constant current (CC) power system is normally used for welding with 4 mm and larger-diameter electrode wires. The control circuit for CC power is more complex since it attempts to duplicate the actions of the welder to retain a specific arc length. The wire feed system must sense the voltage across the arc and feed the electrode wire into the arc to maintain this voltage. As conditions change, the wire feed must slow down or speed up to maintain the prefixed voltage across the arc. This adds complexity to the control system. The system cannot react instantaneously. Arc starting is more complicated with the constant current system since it requires the use of a reversing system to strike the arc, retract, and then maintain the preset arc voltage. With wires at the lower end of this range upto 2.4 mm constant-potential DC power source can be used allowing arc length control by the self-adjusting effect.

Power source requirement may be DC or AC. Normally electrode is connected to positive terminal of DC power source. Sometime depending on the nature of flux AC can be used with single electrode wire or with multiple electrodes where one electrode may be connected to DC and other to AC if independent power sources are to be used.

Consumables:

Electrode wires and fluxes are two major consumables. Wires of structural steel are coated with copper to protect it from atmospheric corrosion and increasing its current carrying capacity while stainless steel wires are not coated with copper.

Flux in submerged arc welding performs more or less the similar functions as the electrode coating in the case of MMA welding, except from generation of shielding gas. However, these fluxes perform additional function of pickup or loss of alloying elements through gas metal and slag metal reactions as the molten flux gets sufficient time to react with molten metal and performs above reactions and then forming slag. Some fluxes require baking before use, to remove moisture which might have been absorbed during storage. Such fluxes should be baked as per manufacturer's recommendations or at 250-300°C for 1-2 hours duration before use.

Fluxes are fused or agglomerated consisting of MnO, SiO_2, CaO, MgO, Al_2O3, TiO_2, FeO, and CaF_2 and sodium/potassium silicate. Particular flux may consist of some of these constituents and other may not be present. Depending upon the flux constituents the base of flux is decided. Also the basicity index of flux is decided on the flux constituents. The ratio of contents of all basic oxides to all acidic oxides in some proportion is called basicity index of a flux. CaO, MgO, BaO, CaF_2, Na_2O, K_2O, MnO are basic constituents while SiO_2, TiO_2, Al_2O3 are considered to be acidic constituents.

When welding with low basicity index fluxes, better current carrying capacity, slag detachability and bead appearance are achieved while mechanical properties and crack resistance of the weld metal are poor. High basicity fluxes produce weld metal with excellent mechanical properties and resistance to cracking, however, bead appearance & current carrying capacity are poor.

As the arc is not visible, being covered with the layer of slag, so it necessitates accurate guidance of the welding head on the weld groove, failing which an improper fusion will result. Further, process can be used only in flat or HV positions. Plates of lesser thickness (less than 5 mm) can not be welded because of danger of burn through which may occur. Circumferential welds cannot be made in small diameter components because the flux falls away.

The quality of the weld metal deposited by the submerged arc welding process is high. The weld metal strength and ductility exceeds that of the mild steel or low-alloy base material when the correct combination of electrode wire and submerged arc flux is used. When submerged arc welds are made by machine or automatically, the human factor inherent to the manual welding processes is eliminated. The weld will be more uniform and free from inconsistencies. In general, the weld bead size per pass is much greater with submerged arc welding than with any of the other arc welding processes. The heat input is higher and cooling rates are slower. For this reason, gases are allowed more time to escape. Additionally, since the submerged arc slag is lower in density than the weld metal, it will float out to the top of the weld. Uniformity and consistency are advantages of this process when applied automatically.

Wire size, Welding Current , Voltage and Wire Speed:

Electrode wire size, welding voltage, current and speed are four most important welding variables apart from flux. Welding current is the most influential variable as it controls electrode melting rate, depth of penetration and the amount of base metal fused. However, very high current shall lead to too much penetration resulting into burn through in the metal being joined, excessive reinforcement and increased weld shrinkage and, therefore, large amount of distortion. On the other hand low current shall lead to insufficient penetration, lack of fusion and unstable arc.

Welding voltage has nominal effect on the electrode wire melting rate but high voltage leads to flatter and wider bead, increased flux consumption and resistance to porosity caused by rust or scale and helps bridge gap when fitup is poor. Lower voltage produces resistance to arc blow but high narrow bead with poor slag removal. Welding arc voltages normally vary from 22 to 35 V.

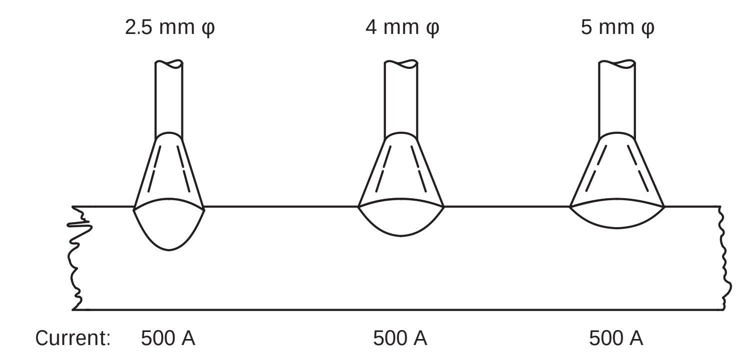
Excessively hard weld deposits contribute to cracking of the weld during fabrication or during service. A maximum hardness level of 225 Brinell is recommended. The reason for the hard weld in carbon and low-alloy steels is too rapid cooling, inadequate postweld treatment, or excessive alloy pickup in the weld metal. Excessive alloy pickup is due to selecting an electrode that has too much alloy, selecting a flux that introduces too much alloy into the weld, or the use of excessively high welding voltages.

If the welding speed is increased, power or heat input per unit length of weld is decreased, less welding material is applied per unit length of weld, and consequently less weld reinforcement results and penetration decreases. Travel speed is used primarily to control bead size and penetration. It is interdependent with current.

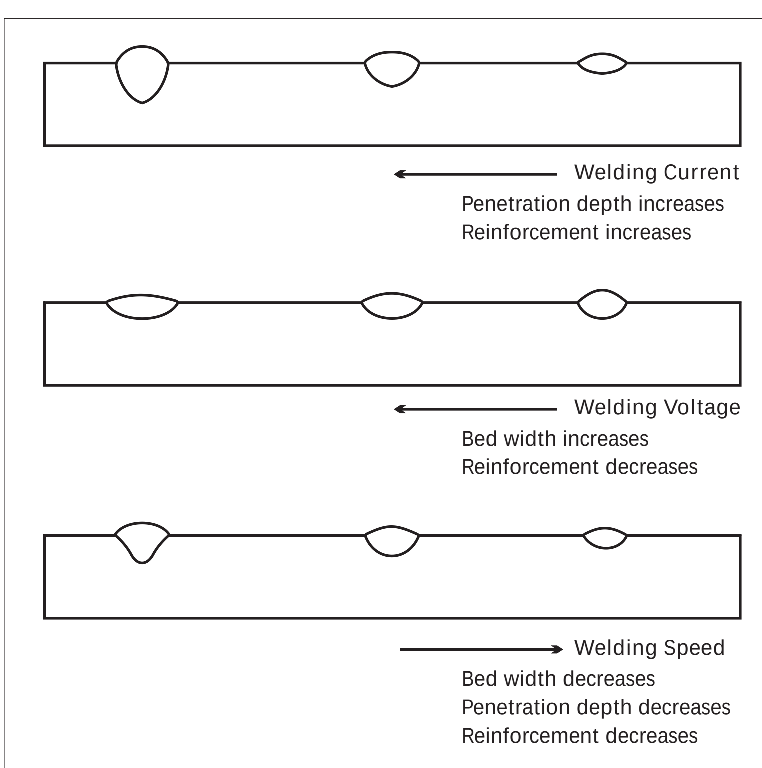
Excessive high travel speed decreases wetting action, increases tendency for undercut, arc blow, porosity and uneven bead shapes while slower travel speed reduces the tendency to porosity and slag inclusion.

The electrode size principally affects the depth of penetration for fixed current. Small wires are generally used in semiautomatic equipment to provide flexibility to the welding gun. The small wires are also used in multiple electrodes, parallel wire setups.

The larger electrodes are generally used to take advantage of higher currents and consequently higher deposition rates. Where poor fit-up is countered a larger electrode is capable of bridging gaps better than smaller ones.



Influence of Electrode Size on Weld Bead.



Influence of Welding Parameters on Bead Shape.

How to improve deposition rate ?

The electrode size is related to the weld joint size and the current recommended for the particular joint. This must also be considered in determining the number of passes or beads for a particular joint. Welds for the same joint dimension can be made in many or few passes, depending on the weld metal metallurgy desired. Multiple passes usually deposit higher-quality weld metal. Polarity is established initially and is based on whether maximum penetration or maximum deposition rate is required.

The secondary variables include the angle of the electrode to the work, the angle of the work itself, the thickness of the flux layer, and the distance between the current pickup tip and the arc. This latter factor, called electrode "stickout," has a considerable effect on the weld. Normally, the distance between the contact tip and the work is 25 to 38 mm. If the stickout is increased beyond this amount, it will cause preheating of the electrode wire, which will greatly increase the deposition rate. As stickout increases, the penetration into the base metal decreases. This factor must be given serious consideration because in some situations the penetration is required.

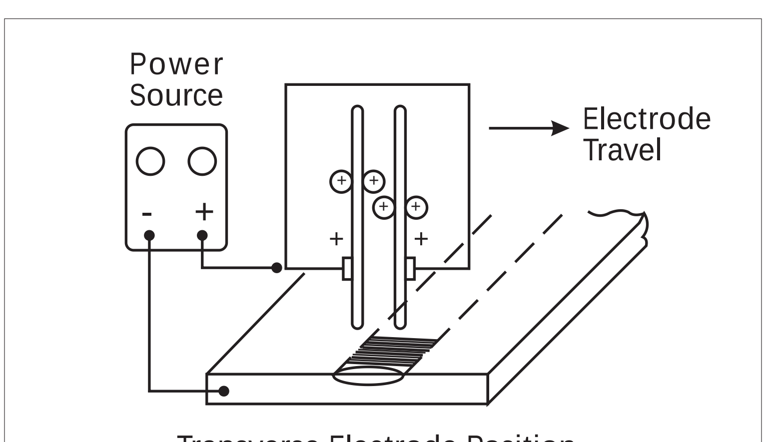
Influence on deposition rate by type of Submerge Arc Welding process:

There are a large number of variations to the process that give submerged arc welding additional capabilities. Some of the more popular variations are:

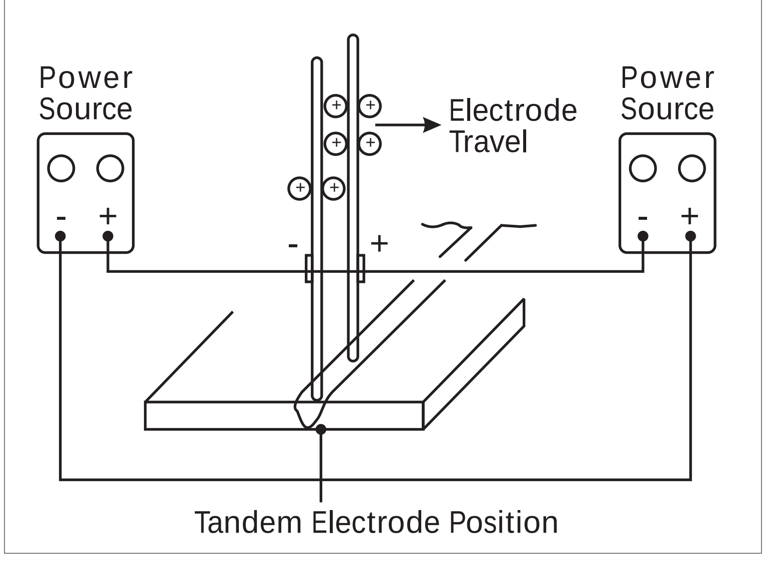
1. Two-wire systems--same power source.
2. Two-wire systems--separate power source.
3. Three-wire systems--separate power source.
4. Strip electrode for surfacing.
5. Iron powder additions to the flux.
6. Long stickout welding.
7. Electrically "cold" filler wire.

The multi-wire systems offer advantages since deposition rates and travel speeds can be improved by using more electrodes. Figureshows the two methods of utilizing two electrodes, one with a single-power source and one with two power sources. When a single-power source is used, the same drive rolls are used for feeding both electrodes into the weld. When two power sources are used, individual wire feeders must be used to provide electrical insulation between the two electrodes. With two electrodes and separate power, it is possible to utilize different polarities on the two electrodes or to utilize alternating current on one and direct current on the other. The electrodes can be placed side by side. This is called transverse electrode position. They can also be placed one in front of the other in the tandem electrode position.

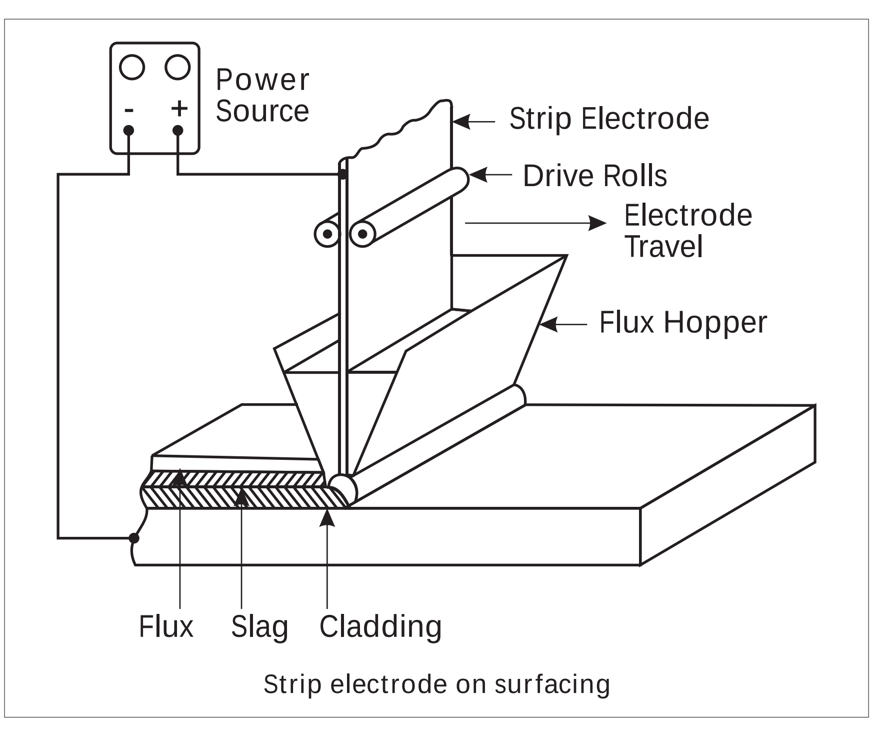
The two-wire tandem electrode position with individual power sources is used where extreme penetration is required. The leading electrode is positive with the trailing electrode negative. The first electrode creates a digging action and the second electrode fills the weld joint. When two dc arcs are in close proximity, there is a tendency for arc interference between them. In some cases, the second electrode is connected to alternating current to avoid the interaction of the arc.



Transverse Electrode Position



Tandem Electrode Position



Strip electrode on surfacing

The three-wire tandem system normally uses ac power on all three electrodes connected to three-phase power systems. These systems are used for making high-speed longitudinal seams for large-diameter pipe and for fabricated beams. Extremely high currents can be used with correspondingly high travel speeds and deposition rates.

The strip welding system is used to overlay mild and alloy steels usually with stainless steel. A wide bead is produced that has a uniform and minimum penetration. This process variation is shown by Figure given bellow. It is used for overlaying the inside of vessels to provide the corrosion resistance of stainless steel while utilizing the strength and economy of the low-alloy steels for the wall thickness. A strip electrode feeder is required and special flux is normally used. When the width of the strip is over 2 in. (51 mm), a magnetic arc oscillating device is used to provide for even burnoff of the strip and uniform penetration.

Another way of increasing the deposition rate of submerged arc welding is to add iron base ingredients to the joint under the flux. The iron in this material will melt in the heat of the arc and will become part of the deposited weld metal. This increases deposition rates without decreasing weld metal properties. Metal additives can also be used for special surfacing applications. This variation can be used with single-wire or multi-wire installations.