Submerged Arc Welding with Long Stickout

By Vivek Pavaskar*

1. INTRODUCTION

Submerged Arc Welding (SAW) process is quite significant in its ability to offer higher deposition rates and arcing time compared to other commonly used welding processes.

For further increasing the effectiveness of SAW process, several techniques and modifications have been evolved. Use of high currents, long stickouts, twin wires with single welding head, auxiliary hot wire additions and multiple welding heads are some of the popular techniques and modifications used for increasing the deposition rate of SAW process.

The extent of usefulness of a particular high deposition rate procedure for production welding depends principally upon the advantages offered by that procedure as regards productivity and weldment mechanical properties within the operational restrictions posed by individual production line and by corresponding shop-floor practice and technique.

This paper focuses on the technique of using long stickout for increasing the deposition rate of single wire SAW process without additional capital expenditure. Discussion in the following pages of this paper is within the context of production features listed below.

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Materials	: Carbon Steels, low alloy steels, Q & T Steels
Joint Thickness	: 20 mm to 50 mm
Joint Design	: Single/Double Vee
Welding Equipment	: Single Wire SAW System—1000 Amps
Welding Technique	: DCRP (E+VE Polarity) 4 mm filler wire, Multipass fill up. Welding speed : 300-400 mm/min.

2. WHY LONG STICKOUT (LSO) TECHNIQUE

We have found that in our fabrication shop, Joint Filling Rate i.e. Kg. of weld metal deposited per metre of joint per welding run or pass (Kg/metre/pass) is the principal factor which determines welding productivity. For steel weldments, the Joint Filling Rate (JFR) is defined as follows :

$$\text{Joint Filling Rate} = \frac{16.7 \times \text{Deposition Rate (Kg/hr.)}}{\text{Welding Speed (mm/min)}}$$

The Joint Filling Rate depends on the ratio of deposition rate and welding speed. Increased joint filling rate reduces the number of passes required to complete a given joint seam and hence reduces the cost of welding.

The joint filling rate can be increased either by reducing the welding speed for the same deposition rate or by increasing the deposition rate. However, there is a limit to which the welding speed can be decreased for a given deposition rate. This limit is decided by the need to have good bead fusion profile and finish. Now our efforts are in the direction of increasing the joint filling rate by increasing deposition rate.

For the welding engineer, trying to improve deposition rate of single wire SAW process to suit production features listed in the introduction, the simplest option available without additional capital expenditure is increasing the current level. However, use of high welding current has its own limitations.

The first limitation is related to the nature of application area. High deposition rate procedures involving use of high currents require extra back up material before they can be put to use without the fear of burn through. In the thickness range 20 to 50 mm with single/double Vee preparation filled up by multipass technique, this becomes a severe limitation, since the high current procedure can be used for a few passes only. The extent of its use is thus limited and its effectiveness in contributing to increased joint filling rate is reduced.

The second limitation is related to mechanical properties of weldment. Use of high current while maintaining same welding speed, directly increases the welding heat input. This increase in welding heat input adversely affects weldment impact toughness and strength. These high heat input procedures thus can not be used for weldments required to meet impact toughness criteria and for weldments involving Q & T steels with high strength requirements.

Faced with above limitations on the use of high welding current, a welding process that offers increased deposition rate at low levels of current would alone find extensive application in terms of range of both joint thickness and types of materials that could be welded.

SAW with long stick out (LSO) technique holds a promise of offering 25% to 50% increase in joint filling rate compared to single wire (4 mm dia) SAW process with standard stickout of 30 mm. For equivalent joint filling rates, SAW with long stickout of 100 mm for 4 mm dia. wire can be operated at current level about 150 Amperes lesser than that of SAW with 30 mm stickout.

From the point of view of operational ease, SAW with LSO technique has the following advantages.

... Allows use of single wire SAW welding equipment with only an appropriate modification in the nozzle design. No additional capital expenditure is involved.

... Does not demand any retraining or reorientation of SAW operator since it offers bead profile similar to that obtained with standard stickout.

In short, SAW with LSO technique is the cheapest way of increasing the joint filling rate by 25% to 50% with least alterations in the conventional single wire SAW equipment, procedures, operation and application area.

The following section outlines the elements essential for successful application of SAW with LSO technique.

3. ELEMENTS OF LSO TECHNIQUE

3.1 Electrical Stickout and Deposition Rate

Electrical stickout is the length of electrically conducting path between the contact tip and the

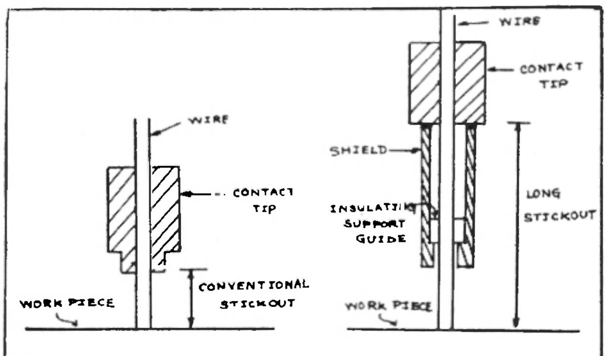

Figure: 1 Concept Of Long Stickout

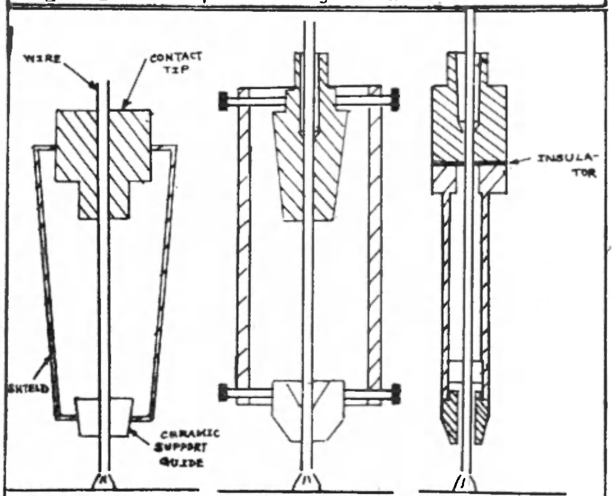

Fig: 2 a) Concept b) Exptl. Model c) Work Model
Design Of Long Stickout Nozzle

TABLE : 1 Predicted Deposition Characteristics With Long Stickout

WIRE DIA (MM)	STICK OUT (MM)	WELDING CURRENT (AMPS) 500				600				700				800				900				1000			
		Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V	Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V	Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V	Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V	Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V	Deposition Rate kg/hr	Wire Feed cm/min	Tip Temp °C	Voltage Drop V
3·2	25	5 8	154			73	194			8 8	234			10·4	276										
	90	9 1	242	1126		12·1	321	1280		15 6	414	1390	5·7	19·6	521	1456									
	120	10·8	287	1340		14·7	391	1456		19·2	510	1500		23·4	622										
4 0	32	5·8	99			7·1	121			8·6	146			10 1	172			11·7	199			13·3	226		
	90	7·5	128	730		9 7	165	884		12 2	207	1016		14 9	253	1126		17·9	304	1214	4·5	21·3	362	1280	5·1
	120	8 5	145	972		11 2	190	1120		14·3	243	1236		17·7	301	1346	5·5	21·6	367	1412		25·9	440	1478	
5 0	40	5 8	63			7·1	77			8·5	93			9 9	108			11·4	124			13 0	141		
	90	6·7	73			8·4	91			10·3	112			12 3	134	730		14·6	159	840		17·0	185	906	
	120	7·3	79			9·3	101	730		11·5	125	862		14·0	152	972		16·7	182	1060		19·7	214	1148	
	150	7·9	86	752		10 2	111	906		12·8	139	1038		15·8	172	1148		19·0	207	1236		22·5	245	1302	4·4

work surface on which arc is struck. Within this length, filler wire is the only current carrying path leading to the welding arc. Fig. 1 illustrates the concept.

The filler wire within the stickout length is resistance heated before it is melted into the arc. As the resistance preheating of the wire increases so does the deposition rate.

The resistance preheating of the wire and hence the deposition rate increases with increase in current, electrical resistance of the filler wire per unit length and stickout length.

Table 1 of predicted values of maximum preheating temperature reached, voltage drop within stickout length and corresponding deposition rate, was prepared to get the feel of phenomenon of resistance preheating for various wire diameters at different current levels and stickout lengths. The predictions were based on empirical and theoretical relations sought from literature (1. 2).

3.2 Choice of Wire Diameter and Stickout Length

The practical stickout length that can be maintained for a given wire diameter and current level is restricted by :

(a) Stability of the arc with preheated wire.

(b) Ability to pass preheated wire through support guides without fouling problems resulting from very flexible hot wire jamming the guide.

(c) The capability of the wire feeder to provide sufficient wire feed rate and capacity of the power source to deliver additional voltage to compensate for voltage drop over stickout length.

Reference to literature (3, 4, 5) on long stickout (LSO) welding for SAW process suggests following practical stickout lengths.

75 mm stickout for wire dia. of 3.2 mm
125 mm stickout for wire dia. of 4 mm
165 mm stickout for wire dia. of 4.75 mm

3.3 Welding Voltage

The "arc voltage" indicated on welding machine voltmeter is in reality the measure of voltage from contact tip to workpiece. Therefore, when setting up the welding parameters for long stickout technique, we have to operate at increased "arc voltage" to compensate for the voltage drop across increased stickout length. The increase in "arc voltage" needed is dependent on wire

TECHNIQUE	DEPOSITION RATE (Kg/h)			
	500 A	600 A	700 A	800 A
SAW Single Wire 4 mm Ø, Stick Out: 30 mm DCRP	5·2	6·7	8·2	10·5
SAW Single Wire 4 mm Ø, Stick Out: 100 mm DCRP	7·0	9·5	11·5	15·0

Table : 2 Comparision of Deposition Rates

diameter, increase in stickout length and the current level.

For 4 mm diameter wire with DC welding current in the range of 500 to 800 Amperes, the "arc voltage" on the meter should be approximately (V+3) volts for stickout of 100 mm, where V is the voltage with conventional short stickout of 30 mm.

3.4 Design of Long Stickout Nozzle

Nozzle design for welding with long stickout was the critical part in the development effort to evolve welding procedure with LSO technique. When the wire extension beyond the contact tip is significant, the wire becomes soft due to resistance heating and the end tends to wander either under magnetic force of the arc or natural cast of the wire. Hence it is essential to provide an insulating guide for the preheated wire, about 40 mm above the arc.

Figures 2(a) through 2(c) show the evolution of the nozzle design from conceptualization stage to final working model. The insulating guide is made from machinable ceramic. The nozzle can support stickout length from 90 to 110 mm for 4 mm dia. wire. This nozzle was so designed that it can be readily fitted on to existing SAW equipment.

3.5 WELDING TRIALS

3.5.1 Deposition Rates

Welding trials were conducted with 4 mm dia. wire with stickout between 90 mm to 120 mm. The electrode polarity was positive. Table 2 lists deposition rates obtained with LSO technique and with standard stickout of 30 mm. It can be seen that LSO technique offers increase in deposition rate of the order of 25% to 50%.

3.5.2 Bead Characteristics

At welding speed between 300 and 400 mm/min. the bead shape and bead finish were satisfactory over the current range 500 to 800 Amperes.

Figure 3 compares the penetration profiles obtained with LSO technique and with standard stickout of 30 mm. Apart from slight reduction in fusion profile, the LSO technique does not result in any significant change in bead geometry compared to standard SAW. The effect of changes in current level, travel speed and voltage when welding with LSO technique are similar to those that are expected in SAW with standard stickout of 30 mm.

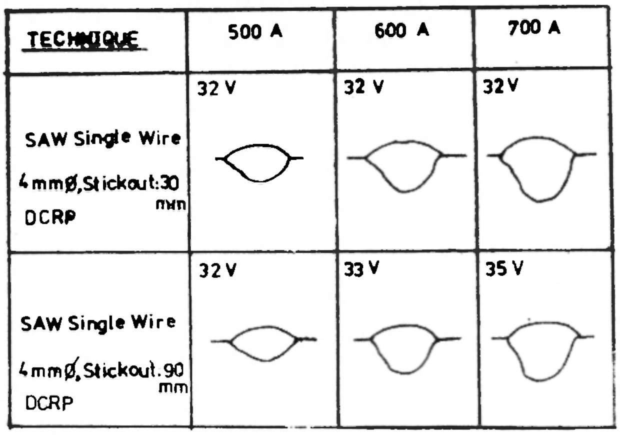

Figure : Comparision of Fusion Profiles

The slight reduction in fusion profile with the use of LSO technique does not seem to be of any consequence in multipass fill up and does not call for resetting the judgement and experience of the SAW welding operator.

3.6 Welding Equipment

For our welding trials with LSO technique, we had selected a SAW welding system with constant current type power source. Apart from problems of arc starting, LSO technique gave trouble free welding. Problem of arc starting was solved by incorporating a minor modification in inching controls. Similar trials with constant voltage type power source systems gave unstable welding conditions, when LSO technique was attempted.

Subsequent to development trials when we conducted further trials to assess suitability of other constant current type welding system in our shop, we found to our surprise, problems in arc stability. We have approached the manufacturer of the welding system with the above problem and are awaiting their comments.

As regards selection of power source, the literature on welding with LSO technique does not indicate any special requirements over and above those for conventional single wire SAW machines. In the introductory paper (5) on welding with LSO technique, J.E. Hinkel of Lincoln Electric—USA writes.

'As a rule, the power source which works well with short stickout is appropriate for welding with long stickout with one exception : some constant voltage power sources that are adequate for short stickout SAW may show weakness with long stickout.'

It is worthwhile that SAW equipment manufacturers take up investigation as regards capabilities of their systems and recommend to their customers how to get maximum out of their systems, when using LSO technique.

4. CONCLUSIONS

(a) Submerged arc welding with long stickout offers increase in joint fillings rate without additional capital expenditure and with least changes/alterations in conventional single wire SAW equipment procedures and operation.

(b) When using DCRP (E+VE) polarity, increasing the stickout length from standard 30 mm to 100 mm for 4 mm dia. wire will contribute to increase of 25% in joint filling rate at current level of 500 Amperes. At current level of 800 Amperes, this increase will be of the order of 50%.

(c) The increase in joint filling rate due to LSO technique is of specific advantage in joints within the thickness range 20 to 50 mm welded by multipass technique with single/double vee edge preparation, where use of high current procedures is limited.

(d) Ability of LSO technique to offer higher joint filling rates at low heat input levels is advantageous for welding of materials where heat input has to be restricted for ensuring adequate mechanical properties.

(e) Using a nozzle specially designed for LSO technique, a welding system with constant current type power source has given us satisfactory welds over current range of 500 Amps to 800 Amps. Weldments made with LSO technique have been qualified to ASME Section IX requirements.

(f) In the light of the advantages that the LSO technique can offer, it is worthwhile that SAW welding equipment manufacturers investigate into suitability of their welding systems for LSO technique.

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