

Electroslag strip cladding



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ABSTRACT:

Technological advancements have driven up temperature and pressure serviced in the petroleum, chemical, pulp, and environmental protection. Industries, and increased the possibility of severe corrosion and wear in process pressure vessels. The industries must upgrade the corrosion and wear performance of these main important parts . Economic features as a rule will not allow fabricating components from solid high alloyed materials. As a result it is essential to surface non-alloyed or low alloy base materials with high-alloy cladding. The submerged arc welding(SAW) and electroslag welding (ESW) process are appropriate for applying welded deposits over large surface areas by means of strip electrodes . Both processes are using a granular flux material. A strip electrode, fed continuously, is liquefied and fused to the substrate. In contrast with other processes it is very effective in spite of the same equipments used but due to the wide strip used it procures a magnetic flow effect within to rectify it a magnetic steering device is exercised. After the welding to examine the defects NDT's are carried upon it.

1. INTRODUCTION:

Electro slag strip cladding is an advancement of submerged arc strip cladding, which has speedily established itself as a reliable high deposition rate procedure. ESW is an arc less technique using Joules Effect to liquefy the strip material. The heating is an outcome of current flowing through the strip electrode and a relatively shallow layer of liquid electro conductive slag as shown in figure 1. The penetration is lesser for ESW than for SAW since the molten slag pool is used to liquefy the strip and some of the flux material

rather than as an arc between the strip electrode and the flux material. As a rule of thumb, electro slag strip surfacing decreases dilution by up to 50% in contrast with submerged arc strip surfacing for the same heat input with a significantly higher deposition rate. However, as a consequence of the lower dilution levels for ESW, new strip compositions have been built for ESW, in particular for applications where the purpose is to obtain a certain weld metal chemistry (such as 304L, 316L) in one layer.

DILUTION:

A significant feature to consider in ESSC is dilution. In any overlay procedure, the weld metal accumulated gets blended with the base metal in the molten state, thus giving a slightly leaner composition. Therefore, the properties of this element of the bead will be somewhat compromised because of the alteration in the chemical composition. The quantity of dilution can be determined by using the formula: -

$$\text{Dilution \%} = (b \cdot 100) / (a + b)$$

As shown in the figure 2, the width ' a ' of the bead will preserve the necessary properties of the clad material, as it practices no change in chemical composition. The quantity of dilution is dependent on the overlay-procedure and procedure variables such as current, travel speed and width of material that will be coupled and also the welding process. Unnecessary base metal dilution, as with other metals, can instilled cracking along the fusion line and must be channeled by using appropriate welding consumable and welding method. Dilution is also an important consideration for ascertaining the number of weld-layers to be imparted for corrosion

resistance. Some multi-pass welded beads may have a little change in composition in each weld layer due to the process control and method employed. The filler metal's first layer should be competent to tolerate at least up to 30% dilution and still should be proficient to produce an acceptable deposit. Welding parameters must be chosen in such a way that fusion with minimum dilution is produced.

2. METHODOLOGY:

2. 1. ESSC

2. 1. 1. WELDING PARAMETERS:

- Attitude of the electrode: The electrode is usually located at right angles to the work piece (vertical) and at right angles to the axis of its movement (relative to the work piece). Rotating the electrode around its longitudinal axis is acceptable to a certain extent, but this will produce a narrower, thicker bead.
- Spacing of current contact: The distance from the lower edge of the contact jaws to the surface to the work piece is generally about 30 mm.
- Flux depth: The depth of the flux determines the width of the slag layer obtained. If the flux is not deep enough, the slag pool will be too shallow, causing improved arcing of the strip. If the flux is too deep, the flux will liquefy only in the middle. The slag pool would be cooled by the flux lying on it, causing deterioration in electrical conductivity. At this point, again, the end result will be increased arcing. Normal depth should be 30 mm.
- Current density: Because of the absence of an arc, the penetration in the ESW procedure is very shallow; this represents that there will be

slight mixing of the filler metal with the melted parent material. It is possible, in evaluation with the submerged arc welding (SAW), to use far higher power levels. For thin layers a normal current density of about 33 A/mm² , 43 A/mm² for thicker layers. For strip type electrodes calculating 60*0.5 mm this will cause 1000 or 1250 A, respectively. This increased current level will cause penetration, though the here is still at the lower limit of what would be predictable in SAW surfacing using a strip type electrode. Power levels exceeding about 1000 A for 60*0.5 mm strip electrode would require very high welding speed to attain thin layers (below 0.15 in - mm) and the strip electrode would break up either wholly or partially from the front edge of the liquid slag. This would outcome in the increased arcing. When using wider electrode strips -120*0.5 mm, for instance—current of > 2500 A may be necessary.

- **Welding voltage:** The welding voltage influences the specific resistance of the liquid slag and will decide how far the strip electrode is to be submerged in the slag pool. Inadequate immersion in the weld pool will affect the process and turn out the process into unstable one. The welding voltage must be lowered as current ascends. A range of 24 to 26 V when operating at 1250 A, or 22 to 24 V for 2500 A, is normal. The precise value will depend on the properties of the flux and the dimensions of the strip. Arcing may be experienced if the voltage is too high and the electrode is not immersed far enough in the slag pool. The welding process will turn out to be unstable with increased arcing.
- **Welding travel speed:** The travel speed will depend on the desired thickness of the surfacing layer. The greater current density which can

be applied along the high melting rate that can be achieved, make it possible to attain higher welding speeds than would be achieved, make it possible to attain higher welding speeds than would be possible with SAW surfacing. A layer of 4mm, is often specified encountered in processing equipment, the welding speed will be between 16 and 20 cm/min. The extent to which the thickness of the cladding can be reduced by increasing the welding speed is limited since, at speed exceeding 20 cm/min, the strip electrode will tend to “ run away from “ the slag pool. For this reason, lower current densities are used to apply thin layers about 3. 5 mm. Not only can the surfacing depth be regulated by adjusting the welding speed; the degree of dilution by the substrate material can also be influenced for two different current levels, in comparison with submerged arc welding.

- Supplementary magnetic fields: With the auxiliary steering magnets switched on, the width of the bead will increase by 1 to 2 mm; the depth is reduced accordingly since the filler material will be pulled toward the outer edges. With suitable adjustment of the magnetic fields at the north and south poles of the magnets will make it possible to affect the shape of the bead. The South Pole is always placed at the left side in the welding direction. Using additional magnetic fields for steering purposes are not required for 60*0. 5 mm electrodes. The geometry of the bead may be unfavorably influenced by welding near the ground connection. The two yokes of the magnet are placed 15 mm to the sides of the electrode strip and 1. 5 mm above the surface of the base material. A strong magnetic field at the South Pole (3A: 1A) will pull the liquid filler material against the natural magnetic blow

direction, which would be to the left when looking at the rear of the electrode. A strong magnetic field at the North Pole (2 A: 1A) would pull in the opposite direction. This is how we can neutralize the natural magnetic blow effect by accurate correction of the two auxiliary magnetic fields.

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2. 1. 2. ESSC Equipments and Machines:

- Strip feed unit: High powered, geared motors are necessary to unwind the strip from the reel and advance the strip electrode in welding process. This is accurate particularly when using wide strip electrodes. Grooved feed rollers matching the thickness of the electrodes will be mandatory.
- Current pick-up unit: Extensive surface power transfer contact units are used, designed to fit the size of the electrode. At least one edge of the contact shoe must be subdivided into fingers which are independently pressed against the strip to make sure the consistent transfer of current across the entire thickness of the electrode. Off-center application of power will result in a non-symmetrical bead, especially when using wider electrodes. When using higher currents in continuous duty operation, it is suitable to fit the rear contacts with water cooling as they are exposed to the thermal radiation from the open slag pool.
- Strip coil mount: The welding strip is usually delivered in coils. Strip measuring 60*0.5 mm, for instance, will weigh from 30 to 60 kg: the weight will augment consequently for wider strip. The strip coil must be engineered to take this load as shown in figure 3.

- Flux feed and removal of excess material: The granular flux material is usually fed out of the flux hopper, and only in front of the strip electrode. Through these means the uncovered slag pool is shaped behind the electrode. The resulting high temperature (2300 degree) ensures improved electrical conductivity within the slag and a procedure which is free of arcing from the strip to the base metal. The flux which is not fused can be vacuum extracted directly after the slag has congealed. It is done with the help of flux recovery or flux recycling machines.
- Remote amperage and voltage control: A necessary component in the strip feed unit is a control unit to keep the welding voltage and current stable. This apparatus must provide an sufficient degree of accuracy while monitoring the welding parameter. Usually in ESSC process in L&T we use NA5 controller for this purpose. A prototype of the equipment with its different controls is shown in figure 4.
- Magnet steering: The slag pool is electro conductive; as a result, the slag pool is subjected to EM forces that tend to make it flow from the edges towards the centre of the molten pool resulting in narrower beads and unfavorable wetting angles. Slag removal becomes tougher and there will be more probability of LF in bead overlap area. Effect of different forces is shown in figure 5.
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To counterbalance for this, magnetic devices are used. This magnetic field is produce by means of two solenoids. The position of solenoids is very important. The tips should be located beside the strip electrode at a distance

of approximately 15mm from the strip edge and about 15 mm above the base material surface.

The form of the solidification ripples should be used to direct the intensity of the magnetic field. The criterion for accurate intensity of the magnetic field is when the solidification lines become symmetrical.

In most cases, the south and north poles of the magnetic control needs distinctive current through each of the solenoids. Start with 3.5Amps at the North and 3.0 at the South. Normally, fix the North magnet 0.5 to 1 Amp higher than the South.

It is observable that the intensity on each solenoid has to be modified according to the working conditions on a specific w/p, taking into account any magnetic blow effect that cannot be considered previously. After the application of the device the shape of the bead is shown in figure 6.

- Welding power supply: The DC current needed for welding is supplied by regular potential rectifiers which are designed to have a plane slope. Discontinuous current cannot be utilized. When using strip measuring 60 *5 mm for ESSC surfacing, the available output capacity should not be less than 1400 A at 100% duty cycle.
- Mechanization welding equipment: Instead of the boom, for regulating minute distances we use cyclomatic slide. It provides both vertical and horizontal movements to the welding head for fine alterations. It uses a 12V DC motor for the purpose; motor rotates the lead screw which transforms it into the linear motion of the nut frame for the alterations.
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ESSC nozzle:

Main operations of nozzle:

- To direct the strip and to maintain it in the required position during welding operation.
- To transfer welding current from power source to the strip by means of suitable contact between shoes and fingers.
- The ESSC nozzle is also equipped with a water-cooling option for strip thickness more than 60mm. nozzle
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2. 1. 3. Welding Consumables:**FILLER METAL USED**

In the framework of Electro Slag Strip Cladding, the filler metal refers to the strip used. The composition of the filler metal is chosen according to the necessities of the job and the dilution expected. The most common prerequisite for cladding is a corrosion resistant internal surface. For this purpose, there are variety of strips available, of distinctive sizes and distinctive compositions. The table1 gives details of the strips:

Type of AWS CLASS	Chemical composition (%)				Remarks
	C	Si	Ni	N	
E308L 24.	0.0.1.	1	9.		For
13L	2	6	5	8.2	1st

		7	5	4	layer
		0.		2	0.For
309L	22.	0.1.	1		0 1st
	11L	3 8	1		
		5	5		4 layer

		0.		2	0.For
309L	24.	0.1.	1		0 2nd
	13L	3 8	1		
		5	5		4 layer

309LC	21.	0.			0.For
		0.2.	2 1	0.	
B	1LN	1			0 1st
	b	2 1	1 1	6	
		5			4 layer

		0.		2	0.For
347L	13.	0.0.	1 2.	0.	0 2nd
	9LN	3 2	0 9	6	
		5	5		5 layer

309Mo	21.	0.	2 1		0.For
		0.1.		2.	
I	14L	1	0.3.	6	0 2nd
		2 8			
		5	5 5		3 layer

					For
316L	19.	0.0.1.	1 1		1st
	12L	2 4 8	8 2		layer

410	12L	0.0.0.	1		For
		1 3 3	2.		2nd
		2	5		layer/

				All
420	13H	0.	1	All
	C	1	4	

Table1: Types of strips with different sizes and composition.

ESSC Flux:

It is required to use fluxes with a high proportion of CaF_2 in order to accomplish the good electrical conductivity desired for the slag at high temperatures while at the same time designing a procedure which is resistant to arcing. Moreover, the fluxes may not include any components which may form gases because they would interfere with the contact needed between the strip electrode and the liquid slag: arcing may result. Flux composition of the flux generally used during ESSC is shown in table 2.

Composites	Percentage
SiO_2	6%
Al_2O_3	25%
$\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}$	4%
$\text{MgO}+\text{CaO}+\text{CaF}_2$	65%

Table 2: Flux composition (in %) used during ESSC process.

Drying of flux: The fluxes are packed dry. Flux used is hygroscopic and will soak up moisture. It is suitable to dry the flux at 300- 400°C for 2 hours prior to use. Transitional storage of flux which has been dehydrated in this way should be in a furnace or kiln at 100°C. It is required to use fluxes with a high proportion of fluoride (Ca F_2) in order to attain the good electrical conductivity desired for the slag at high temperatures while at the same time obtaining a process which is resistant to arcing. Moreover the fluxes may not contain any components which would generate gasses - calcium carbonate (CaCO_3) for instance—since the gasses would interface with the contact needed between the strip electrode and the melted slag; arcing might result. Four fluxes are obtainable, all alike in composition. Marathon 449 gives low silicon pickup and is mainly appropriate for surfacing using nickel based strip electrodes.

2. 1. 4. MAGNETIC BLOW EFFECT IN WIDE STRIPS

The repellent effect of the grounding point has already been pointed, whereby the melted pools are directed to one side, evidenced by off-center rippling of the bead and an off- center end crater. The troubles which result there from become more critical with higher current levels and smaller work pieces. Rising current levels will reinforce the intrinsic magnetic field formed around the electrode in the base material; with small work pieces one is always welding near the grounding connection. It has been found that there is no advantage in using wide electrodes > 4.7 in (> 120 mm) to apply trial cladding to test panels smaller than 40×20 in (1000×500 mm). It can nevertheless happen that, under adverse circumstances, magnetic blow phenomena could be encountered even when working with large

components. Like electric current paths within the slag can be influenced by external magnetic fields. This will initiate modifications in the current density and in the temperature distribution within the slag and will eventually alter the natural direction of flow. When welding the two beads, the grounding pole was attached on the right-hand side, about even with the overlapping point. The pools were consequently displaced outward in each case and beads were created which were thinner in the overlapped area than on the outer sides.

2. 1. 5. HEAT TREATMENTS

The work piece preheating and interpass temperature will depend on the parent material (as a rule 300°C - 1500°C). Thermal post treatments (annealing temperature and time, heating and cooling rates) have to be particular so that the properties of neither parent material nor the cladding will be unfavorably affected. To be given specific consideration are the temperature curve for the parent material, resistant to intercrystalline corrosion, and brittleness of the austenitic cladding. Where multiple layers are applied, stress relief annealing may under certain conditions be undertaken before depositing the final layer. This seems to be favorable for parent materials which require annealing at temperatures beyond (9850 F - 5300 C), one illustration of which is ASTM A387 Gr 22.

Depending on the parent material and the specification, a PHWT at 12750F (6800C) and 32 h will be mandatory. Here it is advisable when dealing with two layers, corrosion-resistant, austenitic ES claddings to weld the first layer with a type 309L strip or a stabilized 309L Nb strip, in order to shield against disbonding.

2. 1. 6. Disbonding

In the early 1970's the Japanese had made experience with hydrogen induced disbanding of stainless steel weld overlay in a desulfurizing reactor. Because the vessel was overlaid by ESSC, this process had become skimmish at many oil companies and therefore the oil companies require tow pass cladding by SAW for that type of work.

Hydrogen in metals tends to concentrate at inclusion, voids and precipitation, or close to them, rather than in the matrix. After PWHT of the thick walled pressure vessels there is a concentration between the overlay and the parent metal.

There is, therefore, under certain conditions, more hydrogen at these precipitates than in the matrix of the first layer of the overlay. During operation of a hydrocracker or hydroesulphurizer (operating conditions of about 450 c and 15MPa) hydrogen diffuses through the stainless overlay and into the 2 ¼ Cr 1 Mo parent material. Diffusibility of hydrogen in stainless steel is lower than in the base metal but the solubility is lower in the base metal. As temperature increases so does the difference in behavior of hydrogen in the two materials. The steady state condition is that there is a higher concentration in the austenitic overlay than the ferritic base metal with a concentration gradient from the weld overlay to the base metal at the transition zone. In conditions of abnormal rapid temperatures and pressure reduction the hydrogen tries to leave the steel but due to the diffusion and solubility characteristics of the material is distributed across the weld overlay with a concentration at the weld-base metal interface. The pressure of

precipitate aggravates the situation and hydrogen embrittlement, so called disbanding can occur.

2. 1. 7. Comparison between single and double layer ESSC:

SINGLE LAYER ESSC: In single layer ESSC, the chief purpose is to attain the desired chemistry with just a single layer of the weld metal. To realize this, the strip chemistry is used in such a way that the diluted weld metal meets the final chemistry in a single layer. As a result, the chemistry of deposited weld metal remains constant throughout the bead height. Nonetheless, to successfully carry out single layer ESSC, a very stringent control over the welding parameters - i. e. current, voltage, welding speed, stick out, bead overlap, flux burden etc. - requirements to be maintained.

DOUBLE LAYER ESSC: Characteristically, a weld overlay procedure consists of minimum TWO layers. The first layer is accumulated with weld metal of richer chemistry (e. g. for a typical Austenitic Stainless Steel, the weld consumable for barrier layer consists of higher Cr & Ni) to take care of dilution from C-Mn steel or Low Alloy Steel flux material. Subsequent layer (s) is accumulated with the weld consumable of same chemistry as that of final requirement. Table 3 shows the parameter for single and double layer.

Sr. No.	Parameter	SINGLE LAYER	DOUBLE LAYER
1.	Layer Thickness	5~6mm	7~9mm
2.	Chemistry Throughout	At least	

	Thickness	4mm	
			from Top
	Deposited		
3.	Weld Metal per m ²	~48 Kg**	~64 Kg**
4.	Heat Input	70% (in comparison to Double Layer)	100%
5.	Average m ² of Overlay per Day	4. 2**	3. 1**
6.	Reduction in Cycle Time	2 Days / MT**	

**The above data is for 60*0. 5mm strip size.

Table3: Effect of parameters on single layer and double layer essc.

From the above table, it is very clear that Single Layer ESSC provides considerable advantages in terms of:

- Overall Cycle time (Welding Time + NDT Time)

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- Welding Consumable Cost
- Overall Heat Input.
- Lesser distortion due to lesser overall heat input
-

2. 1. 8. Comparison between ESSC and SAW:

ELECTROSLAG technique **SUBMERGED ARC technique**

Electro slag strip cladding differs from the submerged arc technique in that the energy required to melt the strip, the base metal and the flux is produced by the Joule effect.

There is no electric arc in the electro slag cladding technique. The agglomerated flux is fed from one side only.

The resulting liquid pool (strip, base metal and melted flux) is electrically conductive. The dimensions of the

There is no fundamental difference between submerged arc welding and cladding. The welding wire is merely replaced with the cladding strip. The equipment is the same, except the head must be adapted to guide the strip.

The principle is the same: the energy to melt the strip and the base metal is supplied by the electric arc struck between them.

deposit can be adjusted using two agglomerated flux magnetic rods, one protect the liquid on each side of the metal and where liquid pool.

The electro slag strip cladding technique is characterized by:

- A higher rate of deposition than the submerged arc technique (22 kg/h),
 - Low dilution with the base metal (7 to 10%),
 - The required chemical analysis can be obtained with one or
- On melting, the flux protect the liquid on each side of the metal and where liquid pool. applicable
- enriches it with alloying elements.
- Submerged arc cladding is characterized by:
- Low penetration generating a low level of dilution (16 to 20%) limiting the number of layers of deposit required (two to three depending on the

- at most two layers, with exceptionally stable and regular operation (this is because of the previous two features),
- The ability to use strips with widths in the range
- required chemical analysis),
- Good chemical homogeneity of the deposit,
 - Low sensitivity to hot cracking (when cladding with nickel alloy) due to the absence of chemical segregation around the deposit (unlike using wire),
 - Possible transfer of alloying

elements
from the
flux
(compensati
on and
enrichment)

- A very flat coating surface,
- A low investment cost on changing over from wire to strip,
- The ability to use strips with widths in the range 30 to 90 mm.

Table4: Comparison between ELECTROSLAG and SUBMERGED ARC technique.

2. 1. 9. WELD DEFECTS: The major defects are slag inclusion, improper bead shape, crater crack, centerline cracks, porosity, under cut.

SLAG INCLUSION:

Slag inclusions are nonmetallic solid material trapped in weld metal or between weld metal and parent metal. Slag inclusions are regions inside the weld cross section or at the weld surface where the once-molten flux used to shield the liquefied metal is mechanically entrapped within the solidified metal. This solidified slag corresponds to a portion of the weld's cross-section where the metal is not fused to itself. This can result in a weakened situation which could impair the serviceability of the component. Inclusions may also appear at the weld surface. Like partial fusion, slag inclusions can arise between the weld and parent metal or between individual weld passes. In fact, slag inclusions are frequently associated with partial fusion. Slag inclusion defect is shown in figure9.

Solution:

- Adjust the parameter to get bead proper slope at toe.
- Maintain accurate bead overlap before start of the overlay. It should be in the 2-5 mm not more than it.
- Appropriate cleaning of the bead with power wire brushing and blades.
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IMPROPER BEAD SHAPE:

Improper bead shape defect is shown in figure 10.

Reasons:

- Incorrect / wrong settings of Magnetic Stripping Device
- Generating jerks in the welding head/ tank rotator.
- Current fluctuation.

- Wrong bead overlap.
- Flux height may be very high.
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Solution:

- Connect shoes face should be polished & tight appropriately.
- Check ear thing lug and power source.
- Establish appropriate current & polarity.
- Set accurate bead overlap.
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CRATER CRACK:

These are minute cracks which ap