# TWIN STRIP ELECTROSLAG CLADDING

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The internal surface of the pressure vessels employed in the petrochemistry industry is often faced with materials which are resist to corrosion. The industrial procedure that conjungates the most productivity with the smaller dilution is thatESSC (Electroslag Strip Cladding). The research wants to exceed the actual limits ofESSC process, scanning the possible advantages introduced from Multi StripTechnique Twin Type.

**KEYWORDS**

pressure vessels, cladding, elektroslag strip cladding, multi strip technique twin type, deposit, creep resistant steel, corrosion, elektroslag plating, elektroslag flux, sub-arc welding.

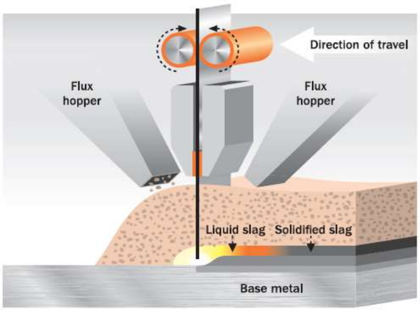
## 1 INTRODUCTION

The strip electroslag cladding was developed in 1990, as integration of electroslag welding process plus today very popular strip cladding process. Aim of this process is deposit by strip intended weld metal (usually corrosion or wear resistant) on base material. Base material has generally good mechanical properties and low price in comparison with overlaying filler material. In *figure 1* strip electroslag cladding is shown.

**Figure 1.** Strip electroslag cladding.

Mainly fromthe economic reason could be strip electroslag cladding used especially in petrochemical industry (pressure equipment, reactors, pipings), offshore industry (pressure equipment, pipings), nuclear and energy industry (tube sheets, pressure vessels, pressure tanks), paper industry (drying ovens, paper drums), ironworks industry (casting rolls and pulleys). For example whole pressure unit shall not be produced from corrosion resistant material, shall be design from low alloy carbon steel and only on surface shall be deposit by strips stainless steel or nickel alloy steel. For these reasons welding process **Subarc Strip Cladding (SASC)** or **Electroslag Strip Cladding (ESSC)**is ideal.

Both processes used strips (standard dimensions 30, 60, 90 mm width and thickness 0,5 mm, but is concern produce also strips width 120 mm), that will provide wide weld beam. For both processes shall be developed special fluxes, that guarantee the best characteristics of deposits. SASC is arc welding method, where welding seam is covered by flux. Function of flux is basically the same as with Subarc Welding (SAW) Method. Flux is forming slag and protects welding pool plus garant good geometry of deposited beam. With ESSC process isn't arc formed between strip and base material, but is formed by flux. Flux is supply only from one side of strip without any recovery. It is also difference SASC has the rest of flux (use rest for recovery), but ESSC has any rest of flux. Pictures of both processes in fig. 2 are shown.



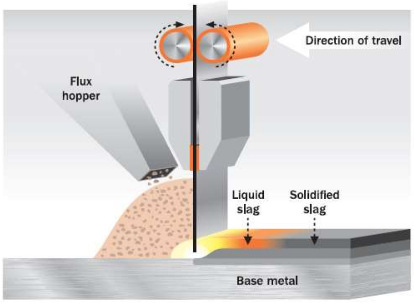




**Figure 2.** Diferences between SASC and ESSC.

During electroslag strip cladding (ESSC) melted strip (by temperature till 2300°C) produce molten pool thickness 2,0 to 3,5 mm. Molten pool is electrically conductive and therefore form overlaying pool by electric resistence. Molten pool is visible in infra-red lights. ESSC on principle has higher penetration and lower dilution than SAW cladding. Cause high temperature of weld pool and high welding current,huge izolated water cooled cladding heads are needed. These high welding currents could also occur irregular geometry of weld deposit and also some defects in welding seam. With a view of continous welding speed of cladding strips (usually wider than 30 mm) magnetic steering devicesare used. Additional to ESSC with higher welding current and higher heat input occurs to higher burn-off some alloying elements compared to SASC. ESSC compared to SASC you can see in Tab. 1. *M*ain advantages are described below: [SAW 2014]

- Higher deposition rate (*Fig. 3*).
- Higher cladding speed.
- Lower dilution (12 %).
- Lower penetration.
- Similar heat input.
- Lower consumption of flux.
- Required deposit (mechanical properties) achieved in single layer.

**Table 1.** Comparison of SASC and ESSC cladding with single strip

| Strip 60x0,5 mm | SASC | ESSC single strip |
|---|---|---|
| | | |
| **Deposition Rate** | 12 -15 kg/h | **20-27 kg/h** |
| **Cladding Speed** | 10-12 cm/min | **18-24 cm/min** |
| **Cladding Voltage** | 26-28 V | 24-26 V |
| **Cladding Current** | 700-800 A | 1200-1450 A |
| **Dilution** | 20 % | 10 % |
| **Penetration** | ≥ 0,8 mm | **< 0,5 mm** |
| **Heat Input** | ≈ 12 kJ/ mm | ≈ 9 kJ/ mm |
| **No. Of Layers** | Min. 2 | **Min. 1** |
| **Deposit Thickness** | ≈ 8,5 mm | **≈ 4,5 mm** |
| **Flux Consumption** | 0,8 kg/ kg of strip | 0,6 kg/ kg of strip |

For the both processes as SASC orESSCare used normal SAW DC power sources. Current capacity for ESSC compare to SASC shall be double and thereby also investment to power sources shall be double or may be triple. Water cooling system and for a most reasons (strips wider then 30 mm) magnetic steering device raise alsothe initial investment. But these higher initial investmants are compensate with higher deposition rate, higher cladding speed, higher productivity with lower penetration and dilution and aslo is possible occur final chemical and mechanical properties of weld deposit in single layer[SAW 2014].

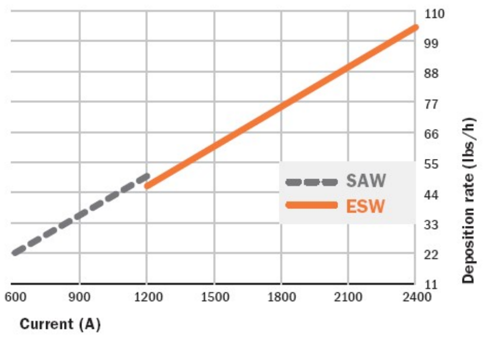



**Figure1.** Comp. Dep. rates of SASC and ESSC strip cladding

## 2 VERIFICATION OF ESSC WITH TWIN STRIPS

The ESSC twin strip process is normal ESSC process, where only both strips get into the same eletrically conductive molten pool. Physical rules, that control ESSC process are also for twin strip process the same. Only with small diffe-rence because cladding current (input) is divided into two strips. In fig. 4 comparison of traditionsl ESSC single and ESSC twin principle cladding is shown. The most demonstra-tive verification of connestion with second strip is raise of electricity conductive liquid metal slag on the surface. Molten spool begins solidify around 20 to 25 mm behind second strip (larger distance for nickel alloy strips).

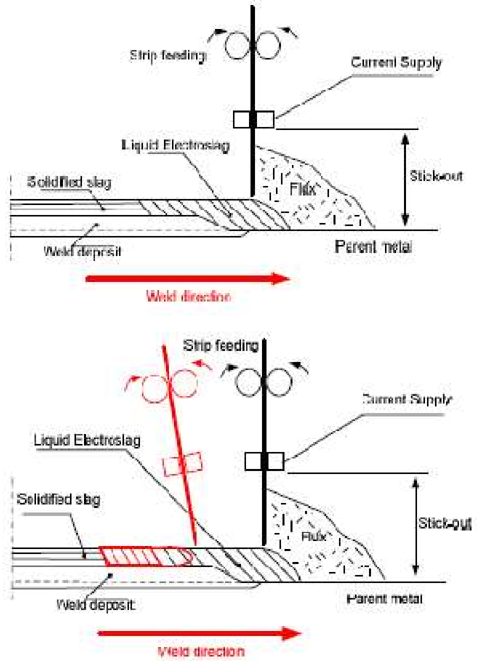



**Figure 4.** Comparison of single and twin ESSC strip cladding

For the main purposes of cladding test plates will be necessary develop, design and produce special electroslag twin strip cladding head. Shall be also upgraded stationary head holder and boom arm for maximum loads. Shall be fixed second strip feeder motor, together with flux feeder, water cooling system and electric cables and so on. ESSC process with two strips were developed to optimize productivity of high alloy layers cladding. ESSC twin strip process also provide higher current density, lower or the same (as ESSC single strip process) penetration and dilution by one layer with using strips width up to 90 mm. Using special ESSC twin strip head open now chapter of electroslag cladding with following objectives:

- Higher productivity by second strip in the same cladding pool.
- Lower penetration.
- Changing of chemical composition to better quality and type of used strip.

The second objective will be verify if this special twin strip cladding head shall be sufficiently resistant and huge frame and also proper for serial production and realcladding.

The analysis of the most used electroslag cladding aplications will be decided verify whole ESSC twin strip process on two types of deposits, of course with two different goals. [Sabatoli 2015]

1/ ESSC twin strip process with stainless steel AISI 347:

The main goals are increasing productivity and influence of chemical composition to analysis of δ ferit, that will provide decreasing of investements. Mainly with possbility deposit stainless steel with correct δ feritnumberon single layer.

2 / ESSC twin strip process with nickel alloy 625:

The main goals are increasing productivity and influence of chemical composition to Fe content in single layer will be reducedbelow7%.

## 3 EXPERIMENT

The main objective of this thesis is realize electroslag cladding by two strips only with single layer, that occur required properties. Experiments take care of both cases stainless steel AISI 347 and also nickel alloy UNS06625.

### 3.1 Experiment of stainless steel cladding on low alloy carbon steel

The base material and preheating and interpass temperature used in experiment.
Base material: ASME SA 542 Tp.D Cl4a (low alloy Cr-Mo-V steel / EN equivalent 2.25Cr-1Mo-V/ 13CrMoV9-10).
Preheating: 120°C. Interpass: 180°C.
Plate thickness 110 mm.
Recommended parameters: Cladding current: 2000 A, Cladding voltage: 25,5 V, Cladding speed 50 cm/min.
Estimated deposit thickness 4,5 – 5 mm.

### 3.2 Experiment of nickel alloy 625 cladding on carbon steel

The base material and preheating and interpass temperature used in experiment.
Base material:ASME SA 516 Gr.65(low carbon steel / EN equivalent S 355 NL).
Preheating: 50°C. Interpass: 180°C.
Plate thickness 80 mm.
Recommended parameters: Cladding current: 1650 - 1720 A, Cladding voltage: 26,2 V, Cladding speed 30 cm/min. Estimated deposit thickness 4,5 – 5 mm.
For the evaluation of a experiments will be applied following mechanical and chemical tests acc. Tab. 3.

**Table 3.** Tests shall be applied acc. these standards

| Test | Standard |
|---|---|
| | |
| Macrographic analysis | EN ISO 17639 |
| Bending test side | EN ISO 5173 |
| Hardness test Vickers HV10 | EN ISO 6507 |
| Micrographic analysis | EN ISO 17639 |
| Chemical analysis | |

ESSC twin strips process comparison to ESSC single strip process will have following advantages (tab. 2):

- Higher deposition rate more then two times.
- Higher cladding speed more then two times.
- Low dilution (15 %).
- Still lower penetration compare to SASC.
- Similar deposit thickness and heat input.
- Required deposit (mechanical properties) achieved in single layer.

**Table 2.** Comparison of ESSC cladding with single strip and ESSC cladding with twin strips

| Strip 60x0,5 mm | ESSC single strip | ESSC twin strips |
|---|---|---|
| | | |
| **Deposition Rate** | 20-27 kg/h | **54-65 kg/h** |
| **Cladding Speed** | 18-24 cm/min | **40-50/cm/min** |
| **Cladding Voltage** | 24-26 V | 24-26 V |
| **Cladding Current** | 1200-1450 A | 1500-2100 A |
| **Dilution** | 12 % | 15 % |
| **Penetration** | < 0,5 mm | **< 1,0 mm** |
| **Heat Input** | ≈ 9 kJ/ mm | ≈ 6 kJ/ mm |
| **No. Of Layers** | Min. 1 | **Min. 1** |
| **Deposit Thickness** | ≈ 4,5 mm | **≈ 4,5 mm** |
| **Flux Consumption** | 0,6 kg/ kg of strip | 0,6 kg/ kg of strip |

## 4 CONCLUSIONS

The goal of this study was improving of cladding parameters on test plates for production and real electroslag cladding with two strips process in specific industrial application.

Regarding to comparison of productivity so ESSC twin strips process get around 50 % increasing of cladding speed against ESSC single strip process. The deposition rate is even around 63 % higher.

Regarding to decreasing of penetration, it was obtain only with alloy 625 electroslag twin strip cladding, together with verfication of decreasing % Fe content. Fe content in test plates were extremely low even below 5 %. Other alloying elements like chromiun and nickel were in allowed tolerantion. It shall be usefull properties especially when we use neutral addition flux. These conclusions shall be verify with more tests.

The main conclusion of ESSC twin strips process of stainless steel AISI 347 shown in deposits comformity of standards for chemical compositions and δ ferit accordingEN 10088-1. Range of δ ferit during one strip electroslag cladding is around 9 % to 10,5 %. But twin strip elektroslag proces shown after tests of twin strip processontest plate decreasing of δ ferit below 8 %, what is absolutely in accordance of specification ASME II part C SFA 5.4 E 347 - XX.

All other mechanical tests on test samples were in accordance with named standards.

The electroslag cladding twin strip process generally before begins of experiment raise a lot of questions. But during collateral experiments were obtain satisfy results.

For the real electroslag clading with two strips directly in production for serial manufacturing will need more test and also improving of cladding parameters (especially relation of cladding speed and cladding current) to get the best productivity properties that electroslag cladding could arrange.


### ACNOWLEDGMENTS

NOTE: Special Multistrip HEAD is actually in a “Patend Pending” phase.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