STRIP CLADDING IN PETROCHEMICAL INDUSTRY

Introduction, New Developments, Applications
Content

- Process review
  - SAW vs ESW
  - Advantages

- Disbonding control

- New developments in ESW
  - High speed fluxes
  - Single layer fluxes

- Applications
  - Strip Cladding nozzles
  - Cladding in pressure Vessels
  - Cladding in pipes
SAW vs ESW

Submerged Arc Strip Cladding (SAW)

- Strip
- Driving rolls
- Contactshoes
- Flux (agglomerated)
- Flux Hopper
- Flux height
- Electric arc
- Liquid slag
- Solid slag
- Liquid metal
- Penetration
SAW vs ESW

Electroslag Strip Cladding (ESW)

Special welding flux
One side flux feeding
No electric arc
Electroconductive slag
Advantages of strip cladding

- Very uniform penetration
- Low dilution levels
- Homogeneous weld metal
- Low crack sensitivity
- Very flat surface
- High reproducibility
- Low flux consumption
Advantages of strip cladding

- Very uniform penetration
- Low dilution levels
- Homogeneous weld metal
- Low crack sensitivity
- Very flat surface
- High reproducibility
- Low flux consumption

Typical values with Classical Welding Parameters

- SAW: 18%
- ESW: 10%

\[ Dilution = \frac{B}{A + B} \]
Advantages of strip cladding

High deposition rates

- **MANUELL ELEKTRODENSCHWEIßEN**
  - UP-1 DRAHT
  - UP-2 DRAHTE
- **FULLDRAHT**
  - PLASMA METAL SPRITZEN
  - PLASMA MIG
- **MIG**
  - RES - 60MM BAND
  - UP - 90MM BAND
  - UP - 120 MM BAND
  - RES - 120MM BAND

Kg/h
Advantages of strip cladding

Homogeneous weld metal
Advantages of strip cladding

Very uniform penetration
Low dilution levels
High deposition rates
Homogeneous weld metal

**Low crack sensitivity**

Very flat surface
High reproducibility
Low flux consumption

Migration to the center with wires

Uniform migration of impurities with strip
Advantages of strip cladding

- Very uniform penetration
- Low dilution levels
- Homogeneous weld metal
- Low crack sensitivity
- Very flat surface
- High reproducibility
- Low flux consumption
Advantages of strip cladding

- Very uniform penetration
- Low dilution levels
- High deposition rates
- Homogeneous weld metal
- Low crack sensitivity
- Very flat surface
- **High reproducibility**
- Low flux consumption

The high reproducibility can be explained by the highly automated character and very stable parameters of the process. There is, for instance, no influence of the movement of a welder.
Advantages of strip cladding

- Very uniform penetration
- Low dilution levels
- High deposition rates
- Homogeneous weld metal
- Low crack sensitivity
- Very flat surface
- High reproducibility
- Low flux consumption

Typical values

(kg flux /kg metallic consumable)

- SAW wire: 0.8-1
- SAW strip: 0.8
- ESW strip: 0.5-0.75
**Stick-out**

Distance between the base metal and the contact shoe

Preheat of strip

Light influence on the SAW process

High influence on the ESW process

### SAW

<table>
<thead>
<tr>
<th>Stick-out</th>
<th>Dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>30mm</td>
<td>20%</td>
</tr>
<tr>
<td>40mm</td>
<td>18%</td>
</tr>
</tbody>
</table>

### ESW

<table>
<thead>
<tr>
<th>Stick-out</th>
<th>Dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>30mm</td>
<td>10%</td>
</tr>
<tr>
<td>50mm</td>
<td>5.5%</td>
</tr>
</tbody>
</table>
Disbonding control

Background

- All test under the standard ASTM G146-01
- What limit of disbonded area can be considered as acceptable?
  - Among standard ASTM G146-01: < 2%
- Soudokay has chosen to work with the CRMC (Material research center of the Creusot)
- Actual values for H2 pressure and working T° are closed to test parameters but the cooling rate used for the test is much more critical than the one met in the hydrocracker itself.
Disbonding phenomena

- Two key words:
  - Hydrogen oversaturation
  - Sensitive microstructure at the interface between a stainless steel weld overlay and the base material of the vessel

Austenitic weld overlay

Martensitic carburized layer

2.25Cr-1Mo Steel

Disbonding crack
Disbonding phenomena

Stationary state

After cooling down

Disbonding

Hydrogen Attack

Hydrogen embrittlement
Description of the Disbonding test

- Welding of the sample.
- Mapping of the bonding between the weld overlay and the base metal: US analysis
- The sample is put under higher pressure of $H_2$ and high temperature
- Relaxing of the samples, ten days at room temperature
- Second mapping of the bonding between weld overlay and base metal
- Determination of the disbonding area in percentage of the total area.
- Micrographic examination of the bonding.
Disbonding phenomena

Test parameters:

- Working temperature: 100°C - 500°C
- H2 pressure: 50 - 150 bars
- Holding time: 48 hours
- Cooling rate: 100°C - 700°C/hr

Example: Strip Cladding of AISI 347 on Cr-Mo steel

<table>
<thead>
<tr>
<th>BASE MATERIAL</th>
<th>WELDING CONSUMABLES</th>
<th>WELDING PARAMETERS</th>
<th>P.W.H.T.</th>
<th>EXPOSURE CONDITIONS</th>
<th>DISBONDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,25Cr-1Mo</td>
<td>SOUDOTAPE</td>
<td>1450 A - 24 V-</td>
<td>690 °C</td>
<td>T° - P H2 - TIME - COOLING RATE</td>
<td>450 °C</td>
</tr>
<tr>
<td></td>
<td>24.12LNb</td>
<td>35 cm/min</td>
<td>30 h</td>
<td>150 bars</td>
<td>150 bars</td>
</tr>
<tr>
<td></td>
<td>+ RECORD EST 136</td>
<td></td>
<td></td>
<td>48 h</td>
<td>48 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300 °C/h</td>
<td>300 °C/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 1,5</td>
</tr>
</tbody>
</table>
Recent developments

Demand for higher productivity

Two solutions:

- Higher deposition rates
  - high speed fluxes

- Lower number of layers
  - single layer fluxes
High speed fluxes

Standard fluxes
- Speed limit: 25 cm/min [9.84 inch/min]
- Deposition rate
  - 22 kg/h, 48.4 lb/h
  - 0.8 m²/h [930 inch²/h]

High speed fluxes
- Speed limit: >35 cm/min [>13.8 inch/min]
- Deposition rate
  - 26 kg/h, 57.2 lb/h
  - 1.1 m²/h [1705 inch²/h]
High speed fluxes

Higher speed = higher dilution
- More over-alloyed strips
- Higher currents

Example

<table>
<thead>
<tr>
<th>Single layer alloy 347</th>
<th>Composition</th>
<th>mm</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Soudotape 21.11.LNb Record EST 122</td>
<td>C</td>
<td>Mn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.03</td>
<td>1.1</td>
</tr>
<tr>
<td>1st</td>
<td>Soudotape 24.12.LNb Record EST 136</td>
<td>C</td>
<td>Mn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05</td>
<td>1.21</td>
</tr>
</tbody>
</table>

60 mm strip: 1250 A – 24 V – 18 cm/min [7.1 inch/min]
1450 A – 24 V – 35 cm/min [13.8 inch/min]
## High speed fluxes: Available grades

<table>
<thead>
<tr>
<th>Quality</th>
<th>Layers</th>
<th>Welding Strip</th>
<th>High speed flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 308L</td>
<td>1° 2°</td>
<td>Soudotape 309L</td>
<td>RECORD EST 136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape 308L</td>
<td>RECORD EST 136</td>
</tr>
<tr>
<td>AISI 316L</td>
<td>1° 2°</td>
<td>Soudotape 309L</td>
<td>RECORD EST 136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape 316L</td>
<td>RECORD EST 136</td>
</tr>
<tr>
<td>AISI 347</td>
<td>1°</td>
<td>Soudotape 24.12L</td>
<td>RECORD EST 136</td>
</tr>
<tr>
<td>AISI 317L</td>
<td>1° 2°</td>
<td>Soudotape 21.13.3L</td>
<td>RECORD EST 136Mo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape 21.13.3L</td>
<td>RECORD EST 136Mo</td>
</tr>
<tr>
<td>AISI 310 MM</td>
<td>1° 2°</td>
<td>Soudotape 310MM</td>
<td>RECORD EST 310MM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape 310MM</td>
<td>RECORD EST 310MM</td>
</tr>
<tr>
<td>Ni-alloy 625</td>
<td>1° 2°</td>
<td>Soudotape 625</td>
<td>RECORD EST 236</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape 625</td>
<td>RECORD EST 236</td>
</tr>
<tr>
<td>Ni-alloy 600</td>
<td>1° 2°</td>
<td>Soudotape NiCr3</td>
<td>RECORD EST 236</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soudotape NiCr3</td>
<td>RECORD EST 236</td>
</tr>
</tbody>
</table>
### Single layer fluxes

#### How to develop a single layer flux?

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>%C</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stape 316L</td>
<td>0,012</td>
<td>18,6</td>
<td>12,7</td>
<td>2,7</td>
</tr>
<tr>
<td>Stape 316L + Record INT 101 (1l)</td>
<td>0,045</td>
<td>14,4</td>
<td>10,16</td>
<td>2,2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>%C</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stape 316L</td>
<td>0,012</td>
<td>18,6</td>
<td>12,7</td>
<td>2,7</td>
</tr>
<tr>
<td>Stape 316L + Record EST 122 (1l)</td>
<td>0,029</td>
<td>16,7</td>
<td>11,4</td>
<td>2,4</td>
</tr>
</tbody>
</table>

### ESW - Single layer flux

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>%C</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stape 316L</td>
<td>0,012</td>
<td>18,6</td>
<td>12,7</td>
<td>2,7</td>
</tr>
<tr>
<td>Stape 316L + Record EST 316-1 (1l)</td>
<td>0,029</td>
<td>19,0</td>
<td>12,8</td>
<td>2,6</td>
</tr>
</tbody>
</table>

AISI 316L

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>%C</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 316L</td>
<td>0,04</td>
<td>17,0 - 21,0</td>
<td>11,0 - 14,0</td>
<td>2,0 - 3,0</td>
</tr>
</tbody>
</table>
**Single layer fluxes**

Compensation for dilution  
Alloying elements in flux  
Example

<table>
<thead>
<tr>
<th>Single/two layer alloy 347</th>
<th>Composition</th>
<th>mm</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>Mn</td>
<td>Si</td>
</tr>
<tr>
<td><strong>1st l</strong> Soudotape 309 Record EST 122</td>
<td>0.03</td>
<td>1.26</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>2nd l</strong> Soudotape 347 Record EST 122</td>
<td>0.02</td>
<td>1.33</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>1st l</strong> Soudotape 347 Record EST 347-1</td>
<td>0.03</td>
<td>1.3</td>
<td>0.58</td>
</tr>
</tbody>
</table>

60 mm strip: 1250 A – 24 V – 16 cm/min [6.3 inch/min]
Variation of chemical composition in 316L deposit

Chromium (% weight)

Voltage (V)

1250A / 16cm/min
Variation of chemical composition in 316L deposit

![Graph showing the variation of nickel content with voltage](image)

**1250A / 16cm/min**
Variation of chemical composition in 316L deposit

Voltage (V)

Molybdenum (% weight)

21 22 23 24 25 26 27 28 29

2.55 2.57 2.59 2.61 2.63 2.65 2.67 2.69

1250A / 16cm/min
## Available grades

<table>
<thead>
<tr>
<th>Quality</th>
<th>Layers</th>
<th>Welding Strip</th>
<th>High speed flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 308L</td>
<td>1°</td>
<td>Soudotape 308L</td>
<td>RECORD EST 308-1</td>
</tr>
<tr>
<td>AISI 309L</td>
<td>1°</td>
<td>Soudotape 309L</td>
<td>RECORD EST 309-1</td>
</tr>
<tr>
<td>AISI 316L</td>
<td>1°</td>
<td>Soudotape 316L</td>
<td>RECORD EST 316-1</td>
</tr>
<tr>
<td>AISI 317L</td>
<td>1°</td>
<td>Soudotape 21.13.3L</td>
<td>RECORD EST 317-1</td>
</tr>
<tr>
<td>AISI 347</td>
<td>1°</td>
<td>Soudotape 347</td>
<td>RECORD EST 347-1</td>
</tr>
<tr>
<td>Ni-alloy 625</td>
<td>1°</td>
<td>Soudotape 625</td>
<td>RECORD EST 625-1</td>
</tr>
<tr>
<td>Ni-alloy 825</td>
<td>1°</td>
<td>Soudotape 825</td>
<td>RECORD EST 138</td>
</tr>
<tr>
<td>Duplex 2209 / 1.4462</td>
<td>1°</td>
<td>Soudotape 22.6.3L</td>
<td>RECORD EST 4462-1</td>
</tr>
</tbody>
</table>
Comparison between three ESW fluxes

Strip Cladding of 625

<table>
<thead>
<tr>
<th></th>
<th>1st</th>
<th>2nd</th>
<th>2nd</th>
<th>1st</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>l</td>
<td>l</td>
<td>l</td>
</tr>
<tr>
<td></td>
<td>Soudotape 625 Record EST 201</td>
<td>Soudotape 625 Record EST 201</td>
<td>Soudotape 625 Record EST 236</td>
<td>Soudotape 625 Record EST 625-1</td>
</tr>
<tr>
<td>C</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Mn</td>
<td>0.30</td>
<td>0.10</td>
<td>0.25</td>
<td>0.08</td>
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<tr>
<td>Si</td>
<td>0.35</td>
<td>0.25</td>
<td>0.29</td>
<td>0.32</td>
</tr>
<tr>
<td>Cr</td>
<td>19.5</td>
<td>21.5</td>
<td>17.4</td>
<td>21.6</td>
</tr>
<tr>
<td>Fe</td>
<td>10</td>
<td>2.5</td>
<td>15.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Mo</td>
<td>8</td>
<td>8.8</td>
<td>7.7</td>
<td>8.9</td>
</tr>
<tr>
<td>Nb</td>
<td>2.8</td>
<td>3</td>
<td>2.9</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>mm</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>4.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
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<td>3</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1100 A – 24 V – 16 and 12 cm/min [6.3 and 4.7 inch/min]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1450 A – 24 V – 35 cm/min [13.8 inch/min]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1250 A – 24 V – 20 cm/min [7.9 inch/min]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Example: alloy 625

<table>
<thead>
<tr>
<th></th>
<th>Deposition rates</th>
<th>Time</th>
<th>Material</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/h</td>
<td>m²/h</td>
<td>h/100 m²</td>
<td>kg/100 m²</td>
</tr>
<tr>
<td>1st l</td>
<td>Soudotape 625</td>
<td>22</td>
<td>333</td>
<td>7326</td>
</tr>
<tr>
<td></td>
<td>Record EST 201</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd l</td>
<td>Soudotape 625</td>
<td>26</td>
<td>182</td>
<td>4732</td>
</tr>
<tr>
<td></td>
<td>Record EST 236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st l</td>
<td>Soudotape 625</td>
<td>23</td>
<td>167</td>
<td>3841</td>
</tr>
<tr>
<td></td>
<td>Record EST 625-1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

60 mm strip: 1100 A – 24 V – 16 and 12 cm/min [6.3 and 4.7 inch/min]
1450 A – 24 V – 35 cm/min [13.8 inch/min]
1250 A – 24 V – 20 cm/min [7.9 inch/min]
Cladding Nozzle 30 ES2-75

- Strip Width: 15-20-30 mm
- Minimum Internal Diameter:
  - Longitudinal: 220 mm [8.66 inches]
  - Circular: 350 mm [13.8 inches]
Cladding Nozzles

Cladding Nozzle 60 ES2-207

- Strip Width: 30 - 60 mm
- Minimum Internal Diameter:
  - Longitudinal: 380 mm [15 inches]
  - Circular: 550 mm [21.7 inches]
Cladding Nozzles

Cladding Nozzle 125 ES1-300

- Strip Width: 30 – 60 – 90 – 120 mm
- Minimum Internal Diameter:
  - Longitudinal: 550 mm [21.6 inches]
  - Circular: 700 mm [27.6 inches]
Cladding of Pressure Vessels

Soudotape 24.12.LNb + Record EST 136

By courtesy of Technip Finland
Example: hydrocracker

90 mm strip, 2250 A, 25 V, 27 cm/min [10.6 inches/min]

By courtesy of Technip Finland
Example: hydrocracker: inlet or outlet nozzle

30 mm strip, 750 A, 25 V, 27 cm/min [10.6 inches/min]

By courtesy of Technip Finland
Example: hydrocracker

Automatic release of the slag

By courtesy of Technip Finland
Example: hydrocracker: bottom of the vessel

By courtesy of Technip Finland
Cladding of pipes

Major problem: introduction of the cladding equipment inside the pipe to use the smallest cladding nozzle to move back the motor reducer
Cladding of pipes

Cladding of 316L with Soudotape 316L and flux EST 316-1

Diameter : 300mm
Stip size : 30x0.5mm
Thank you for your attention