Seleção de materiais resistentes à corrosão (CRA) para dutos flexíveis

Roberta Pires
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Seleção de materiais resistentes à corrosão (CRA) para dutos flexíveis

Agenda

▪ An introduction to flexible pipes
▪ Material in contact with the fluid: the carcass
▪ Carcass Materials
▪ Corrosion Mechanisms
▪ Selecting the right material
▪ Carcass Corrosion Test
▪ Future conditions and its materials
An Introduction to Flexible Pipes
Types of flexible pipes

- TOPSIDE JUMPERS
- OFFLOADING RISERS
- RISERS
- FLOWLINES
- TIE-IN JUMPERS

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Dynamic / Static application

FLEXIBLE RISER: high pressure dynamic application with Teta layer
- Armours
- Anti-wear layer
- Flat steel spiral
- Teta pressure vault
- Pressure sheath
- Carcass

FLEXIBLE FLOWLINE: static application rough bore
- Armours
- Zeta pressure vault
- Pressure sheath
- Carcass

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Material in Contact with the Fluid: the Carcass
Material in contact with fluid: the carcass
Material in contact with fluid: the carcass

- Profiling and spiraling

1. Stainless steel strip’s entrance
2. Successive rolls to deform the strip and obtain the staple shape
3. Machine’s rotation
4. Flexible pipe’s advance

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Material in contact with fluid: the carcass
Mechanical behavior

External pressure

- Hydrostatic collapse
  - 1 vault
  - 2 vaults
Mechanical behavior

- Installation vessel
  - Vertical Laying system
  - Pulley
Mechanical behavior
Material in contact with fluid: the carcass

- **Functions:**
  - Transport of fluids: it is in direct contact
  - Prevents:
    - Collapse due to external hydrostatic pressure during operation and installation
    - Over ovalization due to crushing during installation
    - Damage on the plastic pressure sheath with tools used for work in wells

- **Many stainless steels grades, selected regarding:**
  - Mechanical properties
  - Corrosion resistance
  - Cost
Carcass Materials
Carcass Materials

- **Austenitic stainless steels (Fe-Cr-Ni):** 16 to 26 % Cr and 7 to 22 % Ni.
  - ex.: 304, 304L (18 % Cr / 8 % Ni),
  - 316, 316L (18% Cr / 10% Ni / 2 % Mo)

- **Duplex stainless steels:** austenitic and ferritic phases.
  - ex.: 2205 = S32205 (22 % Cr / 5 % Ni / 3 % Mo)
  - 2304 = S32304 (23 % Cr / 4 % Ni)

- **Super duplex stainless steels:** duplex stainless steels + high contents of Mo, Cr and N.
  - ex.: 2507 = S32750 (25% Cr / 7 % Ni / 4 % Mo)

- **Alloy 31:** Fe-Ni-Cr-Mo alloy
Carcass Materials

No H$_2$S

- 304
- 304L
- 316L
duplex 2304 = S322304
duplex 2205 = S32205

[pH]

[Cost increase]

[Temperature increase]

[Cl]

With H$_2$S

- 316 L
duplex 2304 = S22304
duplex 2205 = S32205
super duplex 2507 = S322750

Alloy 31

[Cl]

*p* indication only as it varies a lot with market

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Selecting the Right Material
Selecting the Right Material

Operator usually does not directly determine material. Operator issues a technical specification containing:
- Water composition, including chlorides, carbonates and any molecule that can affect pH
- Oil chemical composition, including H₂S and CO₂ acid gases
- Pressure,
- Temperature.

Flexible pipe manufacturer calculates fugH₂S and pH

Flexible pipe manufacturer checks its tests database and selects the right material.
Corrosion Mechanisms
**Corrosion Mechanisms**

<table>
<thead>
<tr>
<th>Type of corrosion</th>
<th>Aspect</th>
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<td><img src="image2" alt="Diagram" /></td>
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</tr>
<tr>
<td>Stress corrosion</td>
<td><img src="image5" alt="Diagram" /></td>
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</tbody>
</table>

Not an issue

Stress Corrosion Cracking (SCC)

Intergranular Corrosion

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# Corrosion Mechanisms

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*Pitting*

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Carcass Corrosion Test
Carcass Corrosion Test : Autoclave Tests

- **Test procedure:**
  - Samples are cut in a formed carcass
  - Residual stresses due to profiling
  - Samples contain welds
  - Exposure to the environment in autoclave
  - No electrical contact between samples: avoiding galvanic corrosion
  - Duration = 720 h
Carcass Corrosion Test: Autoclave Tests

Tack welded sample

Standard welded sample

Witness sample

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Carcass Corrosion Test: Autoclave Tests

View of a basket with samples

View of sample holder

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Carcass Corrosion Test : Autoclave Tests

- **Test conditions:**
  - Test performed in deaerated deionized water ($O_2<10$ ppb): $N_2$ bubbling
  - Temperature
  - $pH$
  - $FugH_2S$
  - Chloride content
Carcass Corrosion Test: Autoclave Tests

High pressure autoclaves
Up to 1380 bar
Up to 400°C
Future Conditions and its Materials
**Future Conditions and its Materials**

Technip has a solution for current and future conditions

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>130</th>
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<th>110</th>
<th>90</th>
<th>90</th>
<th>90</th>
<th>90</th>
</tr>
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<tbody>
<tr>
<td>pH</td>
<td>4,70</td>
<td>3,70</td>
<td>3,60</td>
<td>3,80</td>
<td>2,85</td>
<td>2,82</td>
<td>2,83</td>
</tr>
<tr>
<td>FugH_{2}S (mbar)</td>
<td>148</td>
<td>61</td>
<td>10</td>
<td>15</td>
<td>18</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>Chloride content (mg/l)</td>
<td>140300</td>
<td>123000</td>
<td>161900</td>
<td>131000</td>
<td>0</td>
<td>0</td>
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Corresponds to **1200 ppmv (!)** at 1 bar and 40°C

**Real Projects covered**
Future Conditions and its Materials

Developments:

Increase in carcass collapse resistance by increasing thickness and mechanical resistance while keeping as much as possible corrosion resistance.
Thank you