Technical Session

13Cr Linepipes for Offshore Application

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Presentation Outline

- Objective
- Business Case
- Technology Summary
- Potential Value Creation
- Recommendation / Way Forward
Objective

➢ To share on the potential use of 13 Cr Linepipes for Offshore Application under selective operating conditions
Business Case: Why 13Cr? Offer better CO₂ Corrosion in Downhole Tubings & Casing (OCTG)

13Cr Super Martensitic SS materials is highly CO₂ corrosion resistance that could be used for linepipes.
Business Case (con’t) : Basis of developing 13Cr linepipe materials is for CO₂ Corrosion by improving its weldability

Unlike OCTG, 13Cr Super Martensitic SS linepipes have to be welded for joining

<table>
<thead>
<tr>
<th>Material</th>
<th>Weldability</th>
<th>Corrosion resistance</th>
<th>Cost</th>
<th>Others</th>
<th>Performance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel (+ Inhibitor)</td>
<td>Good</td>
<td>Distrust under High temp.</td>
<td>High running cost</td>
<td>Environmental pollution</td>
<td>Strength</td>
</tr>
<tr>
<td>Duplex S.S.</td>
<td>Good</td>
<td>Excellent</td>
<td>Expensive material</td>
<td></td>
<td>Toughness</td>
</tr>
<tr>
<td>Conventional Martensitic S.S.</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td></td>
<td>Weldability</td>
</tr>
</tbody>
</table>

Development of martensitic S.S. pipe with good weldability (DNV13CR)

Design Concept

- Low C + Mn (Base)
  - Cr-Mo-V -Cu-Ni
  (High Hardenability)

- Clean steel
  - Low P, S, O, N
  - Low segregation

- Q&T Heat Treatment
- Quenching; Extremely Rapid Cooling
- Pcm ≤ 0.22%
Business Case (con’t): 13Cr Super Martensitic developed based on DNV 13Cr meets selective operating conditions

- High CO$_2$ resistance – Up to 30bar partial pressure
- Mild Sour Conditions – up to 0.01bar partial pressure (0.15psi) of H$_2$S
- Operating Temperature up to 150 deg C
- Equivalent to X80 ksi strength – No API grades

To reconsider of 13Cr application if water injection will be introduced during operation
Business Case (con’t): Candidates for 13Cr linepipes materials identified

<table>
<thead>
<tr>
<th>Convert formula</th>
<th>FTHP Est. (psi)</th>
<th>CO2 (%)</th>
<th>H2S (ppm)</th>
<th>(H2S (ppm) / 10000 = %)</th>
<th>CO2 pp (bar)</th>
<th>H2S pp (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>SKO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project 1</td>
<td>2246</td>
<td>6</td>
<td>14</td>
<td>20</td>
<td>42</td>
<td>0.002</td>
</tr>
<tr>
<td>Project 2</td>
<td>2395</td>
<td>5.4</td>
<td>20</td>
<td>25</td>
<td>0.002</td>
<td>0.0025</td>
</tr>
</tbody>
</table>

Project 1 and 2 are the potential fields
13Cr Materials Linepipes fulfill the requirements of high CO₂ field at intermediate cost between CS and SS

- For high CO₂ field, the use of normal CS linepipes with Cl is recommended based on the current study
- The cost of 13Cr is 20% lower than SS 316L clad and 400% higher than normal CS
- Delivery of min 8 months for flexible and 10 months for metallurgical clad SS is long delivery period
- 13Cr have been proven and widely used in Europe – more than 75%
Positive results of risk evaluation of 13Cr materials linepipes application

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline survey using Magnetic Flux Leakage is uncertain</td>
<td>• The use of treated seawater (3 plus 1 cocktail) that is potentially to cause corrosion inside the pipelines</td>
<td>• Weldability issue and hydrogen cracking for installation of cathode on the 13Cr linepipe</td>
<td>• Incompatible fitting materials that can cause galvanic corrosion</td>
</tr>
<tr>
<td>• To check on requirement of baseline survey using Long Range UT or Aqua MTM</td>
<td>• To use fresh water</td>
<td>• Using clad pipe for anode joint, conformance of cathode design as per code, close supervision its installation</td>
<td>• Use CLAD or solid CRA material</td>
</tr>
</tbody>
</table>
PWHT is required during installation to prevent Intergranular Stress Corrosion Cracking (IGSCC)

1. Evaluation and verification to meet DNV-OS-F101 & API 5LC requirements.

2. DNV-OS-F101:
   a. Tensile Test (Cross weld and All weld)
   b. Charpy V-notch test
   c. Bend test (root and face bend)
   d. Hardness test


4. Welding Consumables: Duplex SS for root, Super Duplex SS for fill and cap

5. PWHT: 630°C for 5 - 6 minutes.
Mapping of 13Cr Technology Technical Limit against current project portfolio

<table>
<thead>
<tr>
<th>Life Cycle Elements</th>
<th>Pipeline Type</th>
<th>Technology Application</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>CS</td>
<td>Stress based</td>
<td>Stress based No</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td>Stress based</td>
<td>Stress based No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>Industrial Standards</td>
<td>Manufacturer / ISO Standard No</td>
</tr>
<tr>
<td></td>
<td>13Cr</td>
<td>Stress based</td>
<td>Stress based No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>CS</td>
<td>Industrial Standards / Own specification</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>13Cr</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CS, SS, Clad and 13Cr are governed by PTS. Whilst Flexible and NMP are using own specification / standard.</td>
<td>No</td>
</tr>
<tr>
<td>Installation</td>
<td>CS</td>
<td>Industry Standards / Own specification</td>
<td>CS, SS and Clad governed by PTS. Whilst Flexible and NMP are using own specification / standard.</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>13Cr</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry Standards / Own specification</td>
<td>No</td>
</tr>
<tr>
<td>Operations / Inspection</td>
<td>CS</td>
<td>Industry Standards / Own specification</td>
<td>CIMG covers all except 13Cr No</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>13Cr</td>
<td>No</td>
</tr>
<tr>
<td>Integrity</td>
<td>CS</td>
<td>Industry Standards / Own specification</td>
<td>CIMG covers all except 13Cr No</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>13Cr</td>
<td>No</td>
</tr>
<tr>
<td>Abandonment / Decommissioning</td>
<td>CS</td>
<td>Industry Standards / Own specification</td>
<td>Not yet being implemented No</td>
</tr>
<tr>
<td></td>
<td>SS/Clad</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Flexible / NMP</td>
<td>13Cr</td>
<td>No</td>
</tr>
</tbody>
</table>
Technology Summary: Meet DNV 13Cr Linepipes

Mechanical and Chemical Properties Requirements including Weldability

- Corrosion Resistance < 0.127mm/yr
- SSC Resistance (pH 3.5 to 5.5) TM0177 Method A
- HISC Resistance (Hydrogen Embrittlement due to CP)

- To avoid IGSSC, release stress and reduce hardness
  - 600 - 650 deg C for 5 to 10 min
  - Induction heating
  - Rapid cooling

- Use Super DSS (25Cr) for X80 strength
- DSS (22Cr) for root (avoid defect)
- Interpass temp of 150 deg C
Technology Summary (con’t): The use of 13Cr application will reduce the overall cost as well as enhance the overall project delivery

- 4 to 5 month delivery period
- High CO$_2$ corrosion resistance
- Moderate H$_2$S resistance
- Thinner CS Materials with X80 ksi

An alternative materials other than metallurgically or mechanically clad pipes for high CO$_2$ fields
Potential Value Creation: 13Cr is the lowest amongst CRA materials (CAPEX) however slightly higher than CS in installation cost.

Corrosion Allowance (CA) ranges from 3 to 6mm depending on the process condition is required for CS Pipes. Lead to thicker WT compared to 13Cr (no CA is required).

Slow installation lay rate is expected on both 13Cr and 316 clad due to SS welding. 13Cr required PWHT during installation.

Based on OIC experience on regional Malaysian projects.
Potential Value Creation: No maintenance, chemical storage and inspection are required for 13Cr thus lower in operational cost (OPEX)

- **CS Linepipes**
  - Chemical Injection Skid
  - Maintenance/Inspection
  - Operational Pigging
  - Corrosion Inhibitor

- **13Cr Linepipes**
  - Not required any chemical injection skid
  - Not required Maintenance/Inspection
  - Cleaning Pig
  - Not required any Corrosion Inhibitor

13Cr is “Corrosion Maintenance Free” compared to CS linepipes
Potential Value Creation: Life Cycle Cost of 13Cr compared to other products

For LCC > 9 years, 13Cr is more economic compared to CS and 316 Clad but higher than flexible pipes
Way Forward:

- To qualify 13Cr in accordance to DNV OS F101 testing requirements on the above operating parameter conditions

- To investigate the max potential of this linepipes with respect to CO2, H2S and Temperature

- To identify a pilot project for 13Cr linepipes application
THE END