HYPERBARIC WELDING FOR CORROSION RESISTANT ALLOY PIPELINE REPAIR

Sophie Yin | SUT
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Answer the following questions

1. **Why** investigate hyperbaric welding for CRA pipeline repair?

2. **How** is a manual hyperbaric CRA weld executed?

Summary / Conclusions

Questions
Why investigate hyperbaric welding for CRA pipeline repair
CRA Clad and Lined Linepipe

+ Both have 3 mm CRA layer inside carbon steel

+ Metallurgically bonded (clad)
  • CRA plate metallurgically bonded to CS plate
  • Plate to pipe by bend press & weld
  • Can accommodate higher strain

+ Mechanically lined
  • CRA Liner pipe inserted in carbon steel pipe
  • Expand liner to plastically deform
  • Welded overlay ends
316 CRA Pipeline Repair

+ Emergency Response
+ Assess damage
+ Manage raw seawater ingress:
  • Maintain positive pressure
  • Pipeline humps
  • Temporary Clamp
  • Flush with treated seawater
+ Current permanent repair options for minor damage:
  • Grouted sleeve or grinding (dents or gouges)
+ Unqualified permanent repair options:
  • Hyperbaric welding
  • Mechanical connectors
  • Sectional replacement with pipelay vessel
+ Full pipeline replacement
How to execute a manual hyperbaric CRA weld
Diver Operated Emergency Pipeline Repair Spread (EPRS)
Habitat Deployment and Dry Underwater Welding

1. Position cut ends with handling frames
2. Lower habitat, seahorse clamp and transfer chamber over pipeline
3. Module deployed with umbilical and attached to habitat
4. Habitat blowdown, commence welding
Hyperbaric CRA Welding Qualification Trials

Objective
Determine if hyperbaric welding is a feasible option for repair of CRA clad and lined pipelines

Subsea7 Scope
“Complete hyperbaric welding trials to qualify a Proposed Welding Procedure Specification (pWPS)... using 100% manual Gas Tungsten Arc Welding process”
Hyperbaric Welding Procedure Qualification Process

pWPS
Pipe details, welding consumable welding position

Hyperbaric special
• Depth

Weld prep and pass sequence

Specs
Manual TIG

Inconel 625 consumable
Welding equipment, number of welders, interpass temperatures

Hyperbaric special
• Umbilical Length
• Atmosphere
• Habitat temperature

Notes
Qualification of pWPS

+ Non Destructive Testing
  • Visual
  • Ultrasonic
  • Radiographic
+ Mechanical Testing
+ Diver Welder Qualification
Manual Hyperbaric Welding for **Carbon Steel Pipeline Repair**

+ **Welding Equipment inside habitat**
  - Welding torches
  - Heating mats
  - Cutters, Grinders
  - De-gaussing machines
  - Welding masks

+ **Welding Equipment on the vessel**
  - Weld control
  - Welding machine
  - Shielding gas
  - Heating mat machines
RWA Welding in Air

+ Back purge to prevent oxidation
+ Purge Dams
+ Purge Gas
+ Oxygen analyser
+ Tape

This figure has been extracted from AWS D18.1/D18.1M-2009.

2. The Tube Sample. The tube sample was prepared using an automatic orbital "bead-on-plate" weld on the outside diameter of a 2 in [50.8 mm] stainless steel tube. The weld penetrated through the tube wall. The concentration of oxygen in ppm added to the pure argon backing gas for each weld was as follows:

<table>
<thead>
<tr>
<th>No.</th>
<th>1—10 ppm</th>
<th>2—25 ppm</th>
<th>3—50 ppm</th>
<th>4—100 ppm</th>
<th>5—200 ppm</th>
<th>6—500 ppm</th>
<th>7—1000 ppm</th>
<th>8—5000 ppm</th>
<th>9—12 500 ppm</th>
<th>10—25 000 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>10 ppm</td>
<td>25 ppm</td>
<td>50 ppm</td>
<td>100 ppm</td>
<td>200 ppm</td>
<td>500 ppm</td>
<td>1000 ppm</td>
<td>5000 ppm</td>
<td>12 500 ppm</td>
<td>25 000 ppm</td>
</tr>
</tbody>
</table>

Weld Discoloration Levels on Inside of Austenitic Stainless Steel Tube
Manual Hyperbaric Welding for CRA Pipeline Repair

+ Welding Equipment inside habitat
  - TIG torches
  - Heating mats
  - Cutters, Grinders
  - De-gaussing machines
  - Breathing (AGA) masks
  - Heat resistant tape
  - Oxygen content analyser
  - Purge hoses
  - Exhausts

+ Welding Equipment on the vessel
  - Weld control
  - Welding machine
  - Shielding and **purge gas**
  - Heating mat machines
Purge Gas Challenges

+ Oxygen levels increased as soon as tape was removed to start welding
+ Despite having five purge shoes and injecting argon at 50 L/s (i.e. positive pressure)
+ Issue containing purge at 6 o’clock position

ARGON

HELIOX (Helium and Oxygen)

Oxygen analyser
Impact of Depth to Oxygen Sensitivity

Surface welds

-25m welds
# Mechanical Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>All weld tensile</th>
<th>Cross weld tensile</th>
<th>Charpy</th>
<th>Vickers</th>
<th>Chemical analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>&gt;SMYS + 80 At least 80 MPa above minimum yield strength</td>
<td>&gt;18</td>
<td>&gt;SMTS Failure in parent material, above specified minimum tensile strength</td>
<td>&gt;35 with 42 J average at minimum design temperature -30 °</td>
<td>&lt;325</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0.2% Proof Stress (MPa)</th>
<th>% Elongation</th>
<th>Ultimate tensile strength (MPa)</th>
<th>Impact Toughness (J)</th>
<th>HV Hardness (kg/mm²)</th>
<th>Pitting Resistance Equivalent # (%Cr + 3.3 x %Mo + 16 x %N)</th>
</tr>
</thead>
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Microanalysis: “Essentially free from grain boundary carbides, nitrides and intermetallics”

Side Bends: No cracks
Technical Risks for Offshore Campaign

+ Suck and Blow
  • Burn through
  • Spatter
+ CRA Contamination
  • Seawater ingress
  • Carbon contamination
+ Out of roundness
+ **Magnetism**
+ Cut outs, full penetration repairs
+ Repair procedures
+ Soluble purge dams
Hyperbaric welding of CRA clad or lined pipeline is feasible, however qualification of purge set up should consider:
+ Lower threshold of allowable oxygen concentration
+ Functionality of oxygen monitoring equipment in hyperbaric environment
Thank you for listening! Questions?
Welding Enclosures

Back-up

+ Initially procured for mitigating suck and blow (12 o’clock)
+ Now considered for welding at 6 o’clock position
+ Will require diver welder to practice at the surface
+ Several configurations required for different welding positions
+ Long time to establish purge