Study on test procedure development to evaluate pipe properties at HAZ in girth welded portion

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Outlines

/Field girth welding simulation project in NSSMC

Main part: Test procedure development to evaluate pipe properties in HAZ

/Introduction

/Outlines of developing test procedure

/Review of trial test results
  Macrographic examination, CTOD, CVN, Hardness

/Summary
Field girth welding simulation project in Nippon Steel & Sumitomo Metal Corporation

<Objective>
• Better understanding on field girth welding

• Better understanding on properties of HAZ in girth welds

• Feedback on material design

• Better communication with customers
Field girth welding simulation project in Nippon Steel & Sumitomo Metal Corporation

Pipe & Tube business unit

Pipe mills
S’less: Wakayama
UOE: Kashima & Kimitsu
HFW: Hikari & Nagoya

Welding joint marketing & development dep.
(2007~)

R&D Center
Material, Corrosion
Welding, Mechanics

NIPPON STEEL & SUMIKIN Pipeline & Engineering
(Domestic pipeline contractor)

Project organization
Narrow gap PGMAW in 1G position

Pipe size: 323.9mm OD x 53mm WT, Bevel angle: 5 deg.
Pass numbers: 19 pass, Root pass: STT without Cu-backing
Narrow gap PGMAW in 5G position

Pipe size: 273mm OD x 14mm WT,
Bevel angle: 5 deg.
Root pass: STT without Cu-backing
SAW in 1G position

Installation in 2011
Introduction

• Nippon Steel & Sumitomo Metal Co. (NSSMC) is conducting test procedure development to evaluate pipe properties (especially CTOD properties) at HAZ in girth welded portion.

• API-1104 does not cover the test procedure to evaluate base metal properties at HAZ.

• API-RP-2Z covers this area but the recommended welding conditions is deferent from the field girth welding of pipe line constructions.
Outline of the test procedure (for welding)

<Bevel design>
Single-bevel (half-K bevel)  
(Figure shows an example. )

<Welding process>
Mechanized GMAW/PGMAW  
Mechanized SAW

<Welding position>
ASME 1G (Pipe rotating)

Items in this page is same as API-RP-2Z
Outline of the test procedure (for welding)

Welding conditions

<table>
<thead>
<tr>
<th>Weld heat input (kJ/mm)</th>
<th>API-RP-2Z</th>
<th>NSSMC procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>3.0</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td>4.5</td>
<td>0.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preheat/ Inter pass temp. (deg. C)</th>
<th>API-RP-2Z</th>
<th>NSSMC procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.100</td>
<td>100~250</td>
<td>125~150</td>
</tr>
<tr>
<td>100~250</td>
<td>min. 250</td>
<td></td>
</tr>
<tr>
<td>min. 250</td>
<td>Max.50</td>
<td></td>
</tr>
</tbody>
</table>

- NSSMC considered that the main line welding could be covered our proposal for welding conditions.
- An extra larger heat input condition should be considered for the double joint process.
Outline of the test procedure (for CTOD test)

Metallographic examination

<table>
<thead>
<tr>
<th>HAZ straightness</th>
<th>API-RP-2Z</th>
<th>NSSMC procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precrack intersect the etched HAZ for 75% of central 2/3 of the specimen thickness.</td>
<td>Measured the fusion line straightness in 60% of wall thickness. Target value is less than 1.0 mm</td>
<td></td>
</tr>
</tbody>
</table>

| Precrack position for coarse grain specimen | More than 15% of precrack in CGHAZ within *0.3 or 0.5 mm of fusion line. The 15% must be within central 2/3 of the specimen. *0.3 mm for 0.8kJ/mm 0.5 mm for 3.0 & 4.5kJ/mm | 1. Average distance from precrack to fusion line should be 0.5 mm or less. 2. HAZ ratio on precrack should be 80 % or more. 3. Unaltered CGHAZ ratio at fusion line should be 25 % or more |
Outline of the test procedure (for CTOD test)

HAZ straightness

60% of wall thickness

1.0mm or less
Outline of the test procedure (for CTOD test)

Unaltered CGHAZ ratio

Unaltered CGHAZ ratio

Etched HAZ

CGHAZ next to un-refined columnar weld metal
(Unaltered CGHAZ)

Criterion
Total length of Unaltered CGHAZ >= 25% in 60% of wall thickness
Trial test results

<Test pipe>
Grade: API 5L X65QO PSL2
OD x WT: 8.625” x 1.317” (219.1mm x 33.45mm)

<Welding conditions>
1. Low heat input
   Process: PGMAW, Position: 1G
   Aimed heat input: 0.5kJ/mm
   Preheat/ Interpass temp.: max. 50 deg.C
2. High heat input
   Process: SAW, Position: 1G
   Aimed heat input: 1.6 kJ/mm
   Preheat/ Interpass temp.: 125~150 deg.C
Trial test results
Macrographic examination for 0.5kJ/mm GMAW joint

In 60 % of wall thickness
HAZ straightness: 0.76 mm, Unaltered CGHAZ: 64.9 %
Trial test results
Macrographic examination for 1.6 kJ/mm SAW joint

In 60 % of wall thickness
HAZ straightness: 0.98 mm, Unaltered CGHAZ: 52.5 %
## Trial test results

### HAZ straightness & unaltered CGHAZ ratio

<table>
<thead>
<tr>
<th>WPS</th>
<th>Joint ID</th>
<th>Specimen ID</th>
<th>HAZ straightness (mm)</th>
<th>Unaltered CGHAZ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PGMAW 0.5 kJ/mm</strong></td>
<td><strong>M-2</strong></td>
<td>MW-1</td>
<td>0.76</td>
<td>64.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MW-2</td>
<td>0.88</td>
<td>66.9%</td>
</tr>
<tr>
<td></td>
<td><strong>M-3</strong></td>
<td>MW-3</td>
<td>0.68</td>
<td>58.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MW-4</td>
<td>0.73</td>
<td>62.8%</td>
</tr>
<tr>
<td><strong>SAW 1.6 kJ/mm</strong></td>
<td><strong>S-2</strong></td>
<td>SW-1</td>
<td>0.98</td>
<td>52.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SW-2</td>
<td>0.85</td>
<td>57.3%</td>
</tr>
<tr>
<td></td>
<td><strong>S-3</strong></td>
<td>SW-3</td>
<td>0.95</td>
<td>67.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SW-4</td>
<td>0.56</td>
<td>63.8%</td>
</tr>
</tbody>
</table>

In 60 % of wall thickness;
HAZ straightness was controlled less than 1.0 mm
Unaltered CGHAZ ratio was more than 50 %
Trial test results

Average distance from the fusion line to the precrack and HAZ ratio on the precrack

In both case of 0.5kJ/mm GMAW and 1.6kJ/mm SAW;

Average distance from the fusion line to the precrack should be keep 0.2 mm or more to keep the HAZ ratio on the precrack more than 80 %.
Trial test results

CTOD test results

Measured CTOD values were more than 0.25 mm.
Trial test results

Charpy impact test results

The transition temperature of CGHAZ in 1.6kJ/mm SAW joint was higher than 0.5kJ/mm PGMAW joint.
Significant hardening occurred at CGHAZ near the outer surface. Near the inner surface, hardening was not significant.
Trial test results

Hardness distribution in 0.5 kJ/mm GMAW joint

It was confirmed that significant HAZ hardening occurred only in the cap pass region.
Trial test results

Hardness distribution in 1.6 kJ/mm SAW joint

No significant hardening occurred at CGHAZ.
4. Summary

• NSSMC is conducting test procedure development to evaluate pipe properties (especially CTOD properties) at HAZ in girth welded portion based on API-RP-2Z

• Outlines of developing procedure and trial test results were introduced. NSSMC will continue to develop the test procedure to obtain broad consensus with our customers.