Impact of Girth Weld High-Low Misalignment

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Background and Incentives

- Some newly constructed pipelines in the US experienced
  - Hydrostatic failures
  - In-service leaks soon after lines were put in service
- PHMSA issued ADB-10-03 (March 18, 2010)
  - Girth weld quality issues were identified.
  - Some of the contributing factors
    - Improper transitioning
    - High-low misalignment
    - Improper welding practice and/or not following qualified welding procedure
    - Hydrogen-assisted cracking
    - High stresses acting on girth welds from improper pipe support and backfill in hilly terrains
- A joint task group was formed between API 5L and 1104 committees.
  - Expected outcome
    - Set “allowable misalignment”, and/or
    - Pipe dimensional tolerance
Background and Incentives

- Current language in API 1104
  “For pipe ends of the same nominal thickness, the offset should not exceed 1/8 inch (3 mm). When there is greater misalignment, it shall be uniformly distributed around the circumference”

- Is the language adequate?
  - Limiting misalignment makes sense, but misalignment is not the only factor affecting performance.
  - Uniform distribution?
    - Makes sense if when such action can reduce the maximum level of misalignment
    - Misalignment is often caused by local geometry variations (tenting). How could one distribute such misalignment uniformly around the circumference?
    - Even one can uniformly distribute the misalignment, there should be some limit.
  - How is the specification checked in the field?
Impact of Misalignment

- Possible negative impact of high-low misalignment
  - Difficulty in making high-quality root pass
  - Local stress concentration at the geometric discontinuities
    - May contribute to the formation of hydrogen cracks
    - Reduced fatigue life
  - Gross stress concentration due to reduced load-bearing cross-sectional area
  - Increased difficulty in NDT
Phase I Welds

- Two girth welds with intentionally made high levels of misalignment
- **Weld 1:** 36” OD, 0.372” WT, Grade X70
  - Mechanized GMAW on an UOE pipe, girth welding consumable: ER70S-6
  - High-low misalignment between 0.0 and 2.1 mm (misalignment / WT = 0.00-0.22)
- **Weld 2:** 24” OD, 0.500” WT, Grade X70
  - Manual SMAW on an ERW pipe, girth welding consumable: E8045-P2 H4R
  - High-low misalignment between 0.0 and 5.0 mm (misalignment / WT = 0.00-0.39)

Cross-weld region polished + etched:

Cross-weld region not polished or etched:
Observations from Phase I Tests

- **Weld 1 (mechanized GMAW)**
  - The pipe “UTS” variation of approximately 5% was observed.
  - There is a dependence pipe UTS on o’clock position.
  - Weld strength mismatch ratio = ~1.05 (5% overmatching).
  - All “failures” of the cross-weld samples occurred in the base metal.

- **Weld 2 (manual SMAW)**
  - Weld strength mismatch ratio = 0.95 (5% undermatching)
  - There is a load capacity reduction of 9.5% for misalignment up to 39% of wall thickness.
  - The iso-load capacity relation of CRES models captures the highest load capacity reduction.
Phase 2 Welds

- Four girth welds with intentionally made high levels of misalignment
  - 36” (914 mm) OD 0.531” (13.5 mm) WT X70 spiral pipe

- Tie-in WPS
  - Root: E6010
  - Fills and cap: E8010 HP vertical up flux core using M300 bug
Phase 2 – Weld Macro & Hardness Traverse

- 10 kg Vickers hardness traverse
- Specimens from GW #55 & 58 tested

Weld #55 results
- Pipe sides have similar hardness
- WM/BM = 0.89
- HAZ/BM ≈ 1

Weld #58 results
- Pipe sides have dissimilar hardness
  - 12% difference in hardness
- WM/BM = 0.82 and 0.93 (two values for 2 pipe sides)
- HAZ/BM ≈ 1
Phase 2 – Cross-weld Tensile Specimens

- CWTs extracted from weld regions with flaws
- Material characterization tests conducted
- CWT tests of specimens with natural as well as artificial flaws (flaw depth ≈ 3 mm or 0.12”)

Machined Flaw

All dimensions in inches
Phase 2 – Cross-weld Tensile Results

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<table>
<thead>
<tr>
<th>Type of CWT</th>
<th># of CWTs Tested</th>
<th># of CWTs that Failed in the Weld Region</th>
<th># of CWTs that Failed in the Base Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWTs with No Flaws</td>
<td>12</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>CWTs with Natural Flaws</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>CWTs with Artificial Flaws</td>
<td>14</td>
<td>14</td>
<td>0</td>
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</tbody>
</table>
Observations

- The reduction of cross-weld stress capacity is modest even at high levels of misalignment, when there is
  - a smooth transitioned and sufficiently filled weld profile,
  - no excessive weld strength undermatching, and
  - No large flaws

- High levels of misalignment, by themselves, are not necessarily an integrity concern, provided that
  - (1) under static loading,
  - (2) weld having sufficient toughness, and
  - (3) no large flaws.
Observations

- The misalignment management should therefore focus on
  - having well-transitioned weld profiles with sufficient width (not addressed by standard yet)
  - minimizing the likelihood of having large flaws and/or repair them when necessary (addressed by standard)
  - Not having overly-undermatched weld metal (not addressed by standard yet)
Thank You!

- Q&A