Long-Term Repairs for Bulges

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Coking.com
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OVERVIEW

- Is bulging common?
- How bad can bulging be?
- Why do drums bulge?
- So what?
- When should we repair?
- How to repair?
- How long will repairs last?
Is bulging common?

<table>
<thead>
<tr>
<th>Question</th>
<th>Maximum Answer Range</th>
<th>Average Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Vertical Length</td>
<td>3” to 620”</td>
<td>65”</td>
</tr>
<tr>
<td>Average Vertical Length</td>
<td>2” to 50”</td>
<td>23”</td>
</tr>
<tr>
<td>Maximum Circumferential Length</td>
<td>5.5” to 1,074”</td>
<td>547”</td>
</tr>
<tr>
<td>Average Circumferential Length</td>
<td>4” to 1,074”</td>
<td>408”</td>
</tr>
<tr>
<td>Maximum Radial Bulge</td>
<td>.31” to 6”</td>
<td>3”</td>
</tr>
<tr>
<td>Average Radial Bulge</td>
<td>¼” to 6”</td>
<td>2.1”</td>
</tr>
</tbody>
</table>

How bad can bulging be?
Why Do Drums Bulge?

- **Very high stresses**
  (Axial and hoop stresses in the drum may exceed yield during quenching)

- **Material / thickness mismatch**
  (mechanical ratchet or progressive distortion)

- **Flow patterns inside drums**
  (cold / hot spots)

- **Imperfections**
So what?

Higher nominal stresses

Accelerated bulging mechanism

Cumulative fatigue damage (cracks and fires)
When should we repair?
Assessment Techniques

- API 579/ ASME FFS
- Bulging Intensity Factor (BIF)
Can we use API-579 Assessment?

- Sure! Level 3 Assessment only
  (plastic collapse, local failure, buckling, and fatigue analyses)

- Requirements
  1. quantify both mechanical and thermal loads,
  2. simulate how these bulges were formed to account for residual stresses and plastic deformation in bulges (nonlinear model),
  3. use continuum elements to capture stress fields at sharp bulges,
  4. evaluate crack stability or growth if any exist or likely to form, and
  5. incorporate creep damage effects for Carbon steel drums.

- Problems
  - **Cost:** A strain-gage monitoring system, a nonlinear continuum model, and a LOT of labor and computer time can cost $½ to 1 M
  - **Feasibility:** Requirement (2) above may not be achievable!
**BULGING INTENSITY FACTOR (BIF)**

Converts laser scans to severity maps based on a database of cracking history

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Carbon Steel</th>
<th>External Cracking Likelihood</th>
<th>Internal Cracking Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥+2</td>
<td>≥+2.5</td>
<td></td>
<td>SEVERE (End of Economic Life)</td>
</tr>
<tr>
<td>+1.5 to +2</td>
<td>+2 to +2.5</td>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td>+1 to +1.5</td>
<td>+1.5 to +2</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>+0.75 to +1</td>
<td>+1 to +1.5</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>0 to +0.75</td>
<td>0 to +1</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>0 to -0.75</td>
<td>0 to -1</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>-0.75 to -1</td>
<td>-1 to -1.5</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>-1 to -1.5</td>
<td>-1.5 to -2</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>-1.5 to -2</td>
<td>-2 to -2.5</td>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td>≤-2</td>
<td>≤-2.5</td>
<td>SEVERE (End of Economic Life)</td>
<td></td>
</tr>
</tbody>
</table>
BIF Severity Maps

“V. HIGH - SEVERE”
Almost through-wall crack
How to repair?

➢ **Short term**
  - Gouge cracks and re-weld

➢ **Long term**
  - Window replacement
  - Can replacement
  - Weld overlay repair
Window Replacement

Pros and cons
Can Replacement

Pros and cons
Weld Overlay Repair

Proper design
- Thickness Increase
- Favorable residual stresses
- Severity reduction

Improper design
- Excessive distortion/buckling
- Ineffectiveness
- Weld-related cracks/defects
Analysis of Repair
UNKNOWNWS

• Properties of as-welded overlay
• Interaction between overlay material and drum wall (base metal, clad, and seam weld)
• Magnitude of extension of remaining life
INFORMAL JOINT INDUSTRY PROGRAM

• Scope tailored to specific needs and budget of each company

• Results are exchanged at the end, if mutually agreed to by parties

• Testing: Isothermal (high temperature and ambient) and Thermo-mechanical fatigue

• Base Metals: C-½Mo, 1¼Cr-½Mo, others pending

• Overlay: Inconel 625
SUNCOR EXPERIENCE

• Suncor uses the BIF to assess bulging severity and determine the need and extent of repairs.

• Weld overlay repair was used as a long-term solution for one drum and is pending for another.

• Weld repair analysis was conducted using finite element analysis to assess the distortion and estimate the fatigue life.

• A fatigue test program for examining the durability of weld overlay repair and optimizing its application is underway. Phase 1 has been completed and Phase 2 is pending.
Questions?

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