Online Monitoring and Life Extension of Coke Drums

Vipul Gupta
Manager-Inspection, Technical Services
vipulgupta@mrpl.co.in

Vishal F. Yadav
Sr. Manager-Inspection, Technical Services
vishalfy@mrpl.co.in

Sohan S. Alva
GM-Inspection, Technical Services
sohan@mrpl.co.in
Content

- Introduction
- Details of Coke drums
- Coking/De-coking cycles
- Failure modes in coke drums & peripherals
- Inspection and monitoring used in MRPL
- Drum Laser data & severity categorisation
- Strain based engineering analysis observations
- Non-destructive testing (NDT) observations
- Repair methodology and job execution details
- Summary and Conclusion
**Description** | **Details**
--- | ---
Commissioned in | April 2014
Unit Licenser | M/s Lummus Technology
Capacity | 3.0 MMTPA
On-Stream Factor | 8000 Hrs/yr (333.33 days)
Turn Down ratio | 50%
Design feed TAN | < 0.5
No. of Coke drums | 4 nos.
No. of Heaters | 2 nos.
# Details of coke drums

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>M/s ISGEC Yamunanagar</td>
</tr>
<tr>
<td>Total length</td>
<td>41457 mm</td>
</tr>
<tr>
<td>Internal Diameter</td>
<td>9144 mm / 180 inches</td>
</tr>
<tr>
<td>Design coke level</td>
<td>30774 mm</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>SA387 Gr 11 CL1 Base + SA240 410S Clad</td>
</tr>
<tr>
<td>Cylindrical Shell</td>
<td>10 nos. shell courses</td>
</tr>
<tr>
<td>Thickness of cylindrical shell</td>
<td>26 mm to 41 mm with min. 3 mm Clad</td>
</tr>
<tr>
<td>Feed entry nozzle</td>
<td>Side feed</td>
</tr>
</tbody>
</table>
Coking and De-coking cycles
<table>
<thead>
<tr>
<th>Location of failures</th>
<th>Morphology</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell &amp; weld joints</td>
<td>• Bulging and cracking</td>
<td>• Cyclic thermo-mechanical loading</td>
</tr>
<tr>
<td></td>
<td>• Bowing/tilting (banana effect)</td>
<td>• Uneven heating/cooling</td>
</tr>
<tr>
<td></td>
<td>• Weld cracking at tri-metal joints</td>
<td>• Different thermal coefficient of expansion.</td>
</tr>
<tr>
<td>Skirt and concrete foundation failures</td>
<td>• Key hole or weld joint Cracks</td>
<td>• Cyclic thermo-mechanical fatigue</td>
</tr>
<tr>
<td></td>
<td>• Bulging / Buckling</td>
<td>• Uneven load distribution</td>
</tr>
<tr>
<td></td>
<td>• Damage to bolts / structural concrete</td>
<td>• Drum movement /Corrosion/Vibration</td>
</tr>
<tr>
<td>Piping failures</td>
<td>• Cracking</td>
<td>• Vibration induced mechanical fatigue</td>
</tr>
<tr>
<td>Techniques</td>
<td>Occasions/Purpose</td>
<td>Results</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>Laser Mapping and Remote Visual inspection</td>
<td>• Initial inspection</td>
<td>• No fabrication damage</td>
</tr>
<tr>
<td></td>
<td>• August 2017</td>
<td>• Localized bulging-2017</td>
</tr>
<tr>
<td></td>
<td>• August 2018</td>
<td>• Band bulging-2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain based Engineering analysis</td>
<td>• Strain analysis with August 2017 &amp; 2018 Laser data</td>
<td>• Identified areas with high propensity of cracking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAUT/TOFD</td>
<td>• For identifying bulge induced and weld cracking at higher PSI locations.</td>
<td>• Confirmed bulge induced and weld cracking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal inspection &amp; DPT/MPT</td>
<td>• April-May 2019</td>
<td>• Data matched with PAUT/TOFD findings</td>
</tr>
</tbody>
</table>
Drum Laser data & severity categorisation

<table>
<thead>
<tr>
<th>Laser data</th>
<th>Radial growth in mm</th>
<th>Radial growth in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017/2018</td>
<td>33 to 60 mm</td>
<td>24 to 78 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range for ratio of $[(R-Rn)/Rn] \times 100$</th>
<th>Categorization of severity</th>
<th>MRPL drum severity categorisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%-1%</td>
<td>Slight</td>
<td>0-45 mm</td>
</tr>
<tr>
<td>1%-1.5%</td>
<td>Moderate</td>
<td>45-68 mm</td>
</tr>
<tr>
<td>1.5% &gt;=</td>
<td>Severe</td>
<td>69 and above</td>
</tr>
</tbody>
</table>

R- Actual radius measured by Laser mapping  
Rn- Nominal radius of drum
Laser Mapping data of Drum C

Contour plot of the radius (inches) looking from the inside of the drum

- Inward
- Outward

Drum nominal radius is about 180 inches (4572 mm)

Drum C
Seam C4
Outward bulge
Laser Mapping data of Drum D

Drum D-2018: Contour plot of radius (inches) looking from inside of drum

- Inward: Drum nominal radius is about 180 inches (4572 mm)
- Outward: Drum nominal radius is about 180 inches (4572 mm)

Outward bulge

Drum D Seam C-5
# PSI data nomenclature & Drum C, D data

<table>
<thead>
<tr>
<th>PSI data (%)</th>
<th>Drum C</th>
<th>Drum D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max (+)ve</td>
<td>Max (-)ve</td>
</tr>
<tr>
<td>2017 data</td>
<td>(+)45.9</td>
<td>(-)22.2</td>
</tr>
<tr>
<td>2018 data</td>
<td>(+)51.7</td>
<td>(-)21.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PSI magnitude</th>
<th>Severity Grade</th>
<th>Likelihood of Bulging-Related Cracks</th>
<th>Recommended Frequency of Laser Scanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% to 100%</td>
<td>Failure</td>
<td>Likely</td>
<td>6 months to 1 year</td>
</tr>
<tr>
<td>60% to 80%</td>
<td>Danger</td>
<td>Probable</td>
<td>1 year</td>
</tr>
<tr>
<td>40% to 60%</td>
<td>Concern</td>
<td>Possible</td>
<td>1 to 2 years</td>
</tr>
<tr>
<td>0 to 40%</td>
<td>Design</td>
<td>Unlikely</td>
<td>2 to 3 years</td>
</tr>
</tbody>
</table>

**Plastic Strain Index (PSI) values**

<table>
<thead>
<tr>
<th>Positive (+ve)</th>
<th>Inner surface of drums</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative (-ve)</td>
<td>Outer surface of drums</td>
</tr>
</tbody>
</table>
PSI plots of Drum C & D

Drum C-2018: Contour plot of the Plastic Strain Index (%) looking from the inside of the drum

Drum D-2018: Contour plot of the Plastic Strain Index (%) looking from the inside of the drum
Faster deterioration in SA-387 Gr 11 Class 1 drums is attributed to lower strength than Class 2 material typically used in industry.

Inspection of identified bulging zones from inside and outside surface using Visual, DPT, UT.

If cracks observed, design and implement high-quality weld overlay repairs at first shutdown.

Annual laser scanning and strain analysis for bulge assessment
NDT observations

- Inspection performed during de-coking cycles from outside surface.
- PAUT using angle shear beam (for locating ID cracks) and zero deg longitudinal beam (for locating clad disbonding) performed.
- PAUT and TOFD performed for circumferential weld seam examination.
- Weld cracking observed at the interface of tri-metal joint.
- Multiple crack like indications observed in shell plate bulge area scanning, in line with PSI analysis data.
- Circ. length of defect 6-760 mm & depth 1.3-8 mm (from drum ID).
- Three category of defects:
  1) up to 50% of clad
  2) > 50% and within clad
  3) Depth more than clad thickness and penetrating into base metal
Methodology for AWO repair

- Initial inspection, repair area defect confirmation and marking

- Recording of initial data
  1) Grid thickness-for overlay thickness check
  2) Dimensional check-for distortion check
  3) Hardness check
  4) MPI of outside surface for ruling out OD defects.

- Clad removal by arc gouging without pre-heating & finish grinding

- CuSO4 check, PMI and DPT of the finished surface.

- Grit blasting prior to welding to meet SA-3 & primer application

- Fixing of Pre-heating/Post heating pads on drum outer surface, AWO track fixing and machine sequencing.

- Preheating, sealing of clad interface and 1st layer AWO welding
Methodology for AWO repair

- Visual inspection of finished 1st layer, switching off preheating and data collection

- Visual inspection of finished 2nd layer (final layer), including taper at the interface.

- DPT of the interface and post heating.

- Visual inspection and DPT after post heating.

- Removal of AWO tracks and DPT of tack welds after grinding on inner and outer surface (for thermocouple locations)

- PAUT from outer surface of bulge area and PAUT and TOFD for weld seam area.

- Visual inspection and DPT of the insulation support cleats and outer surface of the drums.
Details of job execution
Details of job execution
Drum C overlay extent

**Welding Cross-section at C4**

- **SS 410 Clad**
  - (3 mm min.)
- **Inconel 625 weld restoration after welding of base material**
- **Total height/axial extent**: 1118 mm, 44 inches

**Dimensions**:
- **C5**: 300 mm, 300 mm, 150 mm, 159 mm, 300 mm
- **C4**: 300 mm, 300 mm, 150 mm, 159 mm, 300 mm, 300 mm
- **C3**: 300 mm, 300 mm, 150 mm, 159 mm, 300 mm

**Materials**:
- **Base material**: SA387 Gr 11 Cl 1
  - 0.8 MAX.
  - BOTH SIDE
- **Circumferential weld**
- **Taper**
- **Weld overlay**

**Before**

**After**
Drum D overlay extent

**Welding Cross-section at C5**

- **SS 410 Clad** (3 mm min.)
- **Inconel 625** weld restoration after welding of base material

**Total height/axial extent**

- **1041 mm**
- **41 inches**

**Before**
- 38 mm
- 50-60 mm
- 41 mm

**After**
- Clad
- Weld overlay
- Circumferential weld
- Taper
- Base material
Summary and Conclusion

- Due to cyclic service of the drums, regular monitoring is essential.

- Laser mapping is the starting point, followed by engineering analysis based on bulge severity.

- Results of engineering analysis to be confirmed by further NDT to decide on need for repair action.

- Full circumferential band repair using AWO is recommended over patch repair of bulges.

- Multiple elevation repairs require planned sequencing of jobs.

- Inspection of outer surface of drums is highly recommended post AWO.
Thank You

vipulgupta@mrpl.co.in
vishalfy@mrpl.co.in
sohan@mrpl.co.in