Coke drum Monitoring & Inspection for Fatigue Life and Safety Improvement

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Presentation

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Safety Moment - Consequences of Monitoring & Routine Inspection

- Develop plan for Monitoring during Operation and Perform Routine Inspection / Maintenance
Coke drums and overhead piping systems (Vapor, PSV, Blowdown) undergo severe temperature changes, thermal cycles and movement, including bowing, on a daily basis. This causes failure due to thermal fatigue.

Inexpensive coke drum monitoring program which plant personnel can use from the start of operation to minimize thermal fatigue damage, pro-actively optimize thermal operation, increase awareness towards safety, and to avoid unplanned shutdown.
Factors Effecting Coke Drum Fatigue Life, Safety and Reliability

- (1) Mechanical Design
- (2) Fabrication
- (3) Thermal Operation
- (4) Monitoring of TI’s and Thermal Gradient
- (5) Inspection of Critical Welds
Coke Drum - Common Damage Modes

- Cracking of the support skirt weld to drum shell / knuckle junction and / or skirt bulging
- Cracking and bulges (distortion) of the drum shell mainly at / near circumferential seams
- Overhead nozzle cracking (Vapor, PSV)
- Overhead Piping Component failure
Current Industry Trend/Thermal Fatigue Considerations

- Shorter coking cycle
- Larger coke drums
- Severe thermal gradients during heat-up / switch to coking and during “Quench”
(1) Identify critical welds for inspection and provide means for routine visual inspection

(2) Inspect shell bulges and cladding cracks.

(3) Monitor coke drum skin temperature / gradient using (TI) and keep within “design thermal guidelines”

(4) Verify (bowing) “banana” movement of coke drum

(5) Verify “free” unobstructed movement of drum & piping

(6) Monitor Vibration of drum and overhead piping.
#1. **Identify critical welds for inspection and provide means for routine visual inspection.**

- Provide “Inspection Lanes” and removable insulation support for frequent inspection of critical weld seams, including the following:
  
  (a) Circumferential Welds on Shell
  
  (b) Skirt to Shell / Knuckle Welds
Cracking of skirt attachment weld is probably the most widespread maintenance issue. Skirt cracks could compromise the integrity of drum support and/or cause fire if excessive crack length penetrates shell wall.

Skirt to shell welds are the simplest to access and inspect but typically goes unnoticed due to non-leaky cracks covered with insulation.
Fig #1 – Inspection Lanes at Critical Weld Seam (Removable Insulation)
Figure #2 – Lap Joint Slotted Skirt Junction
Figure #3 – Coke Drum Skirt to Head Girth Seam Weld
# 2. Shell Bulges and Cladding Cracks

- Inspect and monitor all shell bulged areas and circ. seams with disbonded or cracked cladding. These are most likely locations for future thru-wall damage sites.

- Cracking of circumferential seams with thickness transition especially in mid-section of drum.

- Bulge formation and cladding cracks are the result of severe quench and causes thermal or corrosion fatigue.
Fig # 4 : Critical Weld Junction (Circ Seam)
# 3. Monitor coke drum skin temperature / gradient using (TI’s) and keep within “design thermal guidelines”

(a) Using TI’s provided on shell immediately above bottom tangent line and on skirt, verify temperature ramps during heat-up and quench cycles.

(b) Severe transients during heat-up lead to skirt failure. Severe transients during “Quench” lead to shell bulges.

(c) Verify circumferential temperature differential on shell.

(d) If thermal guidelines are not met, consider operational changes / optimization and / or frequent inspection.
Figure #5 – Coke Drum (TI’s & Monitoring)
Figure #6 – Finite Element Analysis

Fatigue Life Evaluation of Coke Drum Support Skirt / Shell Junction Using Transient Thermal Stress Analysis
#4. Verify (bowing) “banana” movement

- Banana movement is caused by uneven cooling of opposite walls of drum, especially during quenching.
- Using the nozzles on top of Coke drum and 2-reference points at 90 degrees apart, the horizontal movement of coke drum can be measured during entire operating cycle including water quench.
- Excessive banana movement is an indication of severe quench and channeling leading to shell bulge. This causes clearance and nozzle loading problems.
#5. **Verify “free” unobstructed movement of overhead Vapor line, PSV system and for Coke Drum:**

(a) The movements should include bowing (banana) effect and thermal effect considering coke drum and line.

(b) Prior to start-up and after the line and coke drum are insulated, verify structural clearances between lines and columns, beams / floor penetrations etc.

(c) Verify structural clearances during operation specially during water quench.
#6. Verify magnitude of vibration of coke drum and overhead piping system

Verify if the vibration is significant during water quench, coking and coke cutting. Measure displacement at top of drum and on the line at significant locations.
Optimize Thermal Gradients (ramps) to address the following key parameters:

- Pre-Heat temperature prior to switch to coking
- Duration of switch to coking
- Transient thermal ramp during ‘Heat-Up’ cycle
- Transient ramp during ‘Quench’ cycle
- Optimize quench rate and schedule
Coke Drum Monitoring Program – Fatigue Life / Safety Improvement (cont’d)

PLANT OPERATION

COKE DRUM LIFE EXTENSION, RELIABILITY AND SAFETY

FW / STRESS ANALYSIS, FEA

FW / PROCESS & OPERATION
# RIL’s TYPICAL PRO-ACTIVE INSPECTION AND MONITORING PROGRAM FOR COKE DRUMS

## On-line/Routine

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<tr>
<th>Component</th>
<th>Inspection Method</th>
<th>Frequency</th>
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<td>Skirt</td>
<td>16-window inspection lanes: Visual</td>
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<td>Anchor bolts: Visual, UFD (2yrs)</td>
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<td>TXI data review (Six monthly)</td>
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<td>Banana movement (Six monthly)</td>
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<td>Supports: Visual (3-5yrs)</td>
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## Offline (e.g. during pigging/shutdowns)

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<tr>
<td>Skirt</td>
<td>Visual, MPI, PA-UT (every pigging)</td>
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<td>Ext PAUT @ Nozzles (every shutdown)</td>
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<td>Hardness surveys of clad/welds (every shutdown)</td>
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<td>High Stress Nodes</td>
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# TYPICAL INSPECTION / MONITORING FOR KNUCKLE / SKIRT

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**Legends**
- **OK**: No visual indication of any crack.
- **HLC**: Hairline crack like indication visible.
- **NI**: Not inspected this time due to improper cutting of glass wool / obstruction of alt drain line or scaffolding pipe.
- **NA**: Not available.
- **Indications “as is” wrt last inspection**: Indications increased wrt last inspection.
- **New indications observed this time**: New indications observed this time.

<table>
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<th>Knuckle</th>
<th>no. of drums</th>
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<td>Total drums with HLC visible</td>
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TYPICAL SKIN TXI LOCATIONS, MONITORING

DRUMS R01/R03/R06/R07 - PROPOSED NEW SKIN TC LOCATION

8x4eq dist
TXI's
**Nomenclature**

**Knuckle**
(mapping on outside of the drum circle)

For example,
K1.5(7)W

Where,
K=knuckle
1.5=length of crack in m
(7)=max depth of crack in mm

**Shell**
(mapping on inside of the drum circle)

For example,
5C1.5(7)W

Where,
5C=5th Circ weld (from btm cone) on shell
1.5=length of crack in m
(7)=max depth of crack in mm
BANANA MOVEMENT

Measurements taken by attaching pointer to “TUD” and plotting the “Poler” plots.

Pointer is attached to the top unheading device. This is used to plot the banana movement.
HIGH STRESS NODES

Critical stressed locations mapping and criticality ranking
Periodic inspection at frequencies based on criticality
SUPPORT MODIFICATIONS CARRIED OUT TO REDUCE VIBRATIONS

- Support modified
- Rigid support removed

- Support modified
- Rigid support removed
Thank You