The Latest Advancements in Delayed Coke Drum Inspection & Reliability Techniques

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Widely recognized as the world’s leading coke drum inspection company with 1300+ site inspections realized for industry’s leading refiners.

Forefront of innovation in non-destructive examination (NDE) techniques for the delayed coking industry and proud to play a continued lead role in improving operator safety, asset life and unit output.

First invented the technique and continues 100% dedicated and focused to the inspection of delayed coke drums with a 25+ year history and more than 150 years of collective expertise.

Specific to India, 15+ years experience with over 160 inspections completed making India one of CIA’s most important markets, and CIA India’s leading DCU inspection company.

Driven by continuous improvement and value add services, CIA has evolved into a full service partner in coke drum inspection and reliability services.

The following slides demonstrate CIA’s comprehensive coke drum inspection package that form part of the standard offering:
FULL SERVICE PARTNER IN DRUM RELIABILITY

Laser Profile – a remotely deployed, laser-based range imaging tool designed to profile the internal surface of “online” coke drums in order to locate and measure vessel distortions in an accurate and consistent manner.

Remote Visual – best in class, state of the art, high-definition (HD) digital video camera with zoom capabilities to visually inspect the internal surface condition, including the dome, cone and nozzles.

Robotic Crack Detection – a telescopically deployed robotic crawler equipped with an NDE sensor (ACFM) used to characterize and size surface breaking cracks.
CIAI understands the operational issues affecting delayed coke drums and the factors that contribute to drum deterioration. Operating under severe conditions of cyclic heating and forced cooling, coke drums distort and "bulge" in service. It has long been recognized that the ultimate failure mechanism for coke drums is weld cracking initiated, in or at close proximity to, the circumferential welds, and it is these "bulges" that are often associated with drum failure.

Utilizing state of the art measurement tools and customized software, CIAI's team of inspection specialists are trained to focus on these specific areas of concern and to identify trends and patterns occurring within the coke drum. By offering a wide range of services and solutions, as outlined below, CIAI provides refinery clients with the necessary tools and information needed to better understand and manage overall coke drum reliability.

Solutions for Improved Coke Drum Reliability

- **TRACK & TRENDING VESSEL DISTORTION**
  - Section and polar plot views of selected areas are plotted from the same bulge map to allow the refinery to better monitor the drum profile and understand where, and by how much, the drums are changing. The most recent scan result from 2011 (shown in red) is easily compared to the previous scan result from 2009 (shown in green) and the base radius (shown in blue).

- **VISUAL INSPECTION INDICATIONS**
  - CRACK IN TOE OF WELD
  - STRESS CRACKING OF CLADDING
  - CRACK IN WELD OVERLAY
  - To further verify internal drum conditions and accurately locate surface irregularities, the elevation and azimuth are permanently recorded in a 1:1 correlation between the laser scan and remote visual inspection findings.

CIAI's trademark imaging software, "DrumView", processes millions of data points to create an accurate flat surface representation or "bulge map" of the coke drum. The colours represent year over year variances in drum radius with green depicting the base radius, the warmer colours (yellow to red) identifying outward distortions, and the cooler colours (blue to purple) showing inward distortions. Weld seam overlays are added for location accuracy.
LASER PROFILING - TRACKING & TRENDING

VERTICAL SECTION COMPARISON

Az = 39.2 -0.32 ==> +1.65
Az = 44.5 -0.10 ==> +1.89
Az = 50.8 +0.11 ==> +2.00

POLAR PLOT COMPARISON ACROSS 4th CIRC WELD

0º
162.00
315º
90º
45º
225º
135º
270º
180º
4
2

Elevation (inches)

Azimuth = 49.7

Radius (inches)

2013 - sample
2015 - sample

2013 - sample
2015 - sample

VISUAL INSPECTION INDICATIONS

STRESS CRACKING OF CLADDING
CRACK IN WELD OVERLAY
CRACK IN TOE OF WELD

To further verify internal drum conditions, laser scan and remote visual inspection findings.

The drum image or bulge maps are a flat surface representation or “bulge map” of the coke drum. The colours represent year over year variances in drum radius with green depicting the base radius, the warmer colours (yellow to red) identifying outward distortions, and the cooler colours (blue to purple) showing inward distortions.

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CIAI understands the operational issues affecting delayed coke drums and the factors that contribute to drum deterioration. Operating under severe conditions of cyclic heating and forced cooling, coke drums distort and crack initiated, in or at close proximity to, the circumferential welds, and it is these “bulges” that are often associated with drum failure.

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Section and polar plot views of selected areas are plotted from the same bulge map to allow the refinery to better monitor the drum profile and understand where, and by how much, the drums are changing. The most recent scan result from 2011 (shown in red) is easily compared to the previous scan result from 2009 (shown in green) and the base radius (shown in blue).
CIA presenter to run live demonstration of “DrumView”, CIA’s trademark drum imaging software program
CIAI has the unique ability to position a specific drum's distortion history in comparison with the general population. This "Bulge Comparison Chart" clearly shows refinery clients how their drums relate to other drums in the industry. Using the results of CIAI services, the above site repaired problematic areas of their coke drums and positively altered the projected degradation curve (from pink to green).

The section view and bulge map indicate a sharp distortion at the circumferential weld and the visual inspection confirms the presence of crack-type indications in this area. The ability to correlate the results from CIAI's range of inspection techniques allows the refiner to immediately focus on high-risk, failure prone areas.

After a crack-type indication has been identified, this follow-up service measures the length and depth of the surface-breaking indication. The robotic crawler (shown left) was mounted on a custom built coke drum wall segment with simulated crack-type indications for use in CIAI's validation trial and training for its certified technicians. Typical data outputs (shown above) which include Bx (crack depth), Bz (crack length), and Contour View (for accurate flaw location) measurements are stored as permanent digital records for future reference and comparison.

* Similar charts are available and or under development to track various features including drum design (i.e. vertical plate), unheading devices, bulge sharpness, weld overlay repairs, cycle time, etc.
LASER PROFILING – CONE MAPPING
LASER PROFILING – DRUM BOW ESTIMATIONS
LASER PROFILING – HIGH DENSITY SCANNING
HI-DEFINITION (HD) DIGITAL VISUAL INSPECTION

Typical T-Junction Weld (standard HD inspection)

XYZ Refinery, Drum X_Circ X_elevation xxx, azimuth xxx°

Typical T-Junction Weld (focused HD inspection)

XYZ Refinery, Drum X_Circ X_elevation xxx, azimuth xxx°

Stress Cracking of the Cladding

XYZ Refinery, Drum X_Circ X_elevation xxx, azimuth xxx°

Cladding Delamination

XYZ Refinery, Drum X_Circ X_elevation xxx, azimuth xxx°
HI-DEFINITION (HD) DIGITAL VISUAL INSPECTION

Typical Weld – Clad Transition

Corrosion Pitting

Corrosion Pitting (focused HD inspection)

Metal Weld Overlay
HD VIDEO INTEGRATED INTO “DRUMVIEW”

CIA presenter to run live demonstration
Integration of Hi-Definition Digital to Laser Mapping findings
The below section views show minor year-over-year growth across the 4th circ weld region. These specific regions were selected because of the relatively high bulge severity or sharpness ratings calculated prior to the inspection. Review of the visual images from this area does not show evidence of linear indications or surface irregularities.

2015 - sample  +0.91 ==> +1.88
2013 - sample  +0.26 ==> +1.20
THE INNOVATIVE BREAKTHROUGH

INTERNAL ROBOTIC CRACK DETECTION

An independent research project into Robotic Crack Detection, undertaken by CIA Inspection.

US Patent No. 7,940,298
B2 Issued May 10, 2011
ROBOTIC CRACK DETECTION USING ACFM

Rotary Drive

Video Camera

Laser System

Tilt Drive

Light Weight Boom

Robotic Crawler equipped with an NDE Sensor
APPLYING ACFM TO A COKE DRUM

In conclusion, remote ACFM crack detection works in the coke drum environment and is a useful tool that minimizes downtime while providing accurate results. The technology provides confidence in those findings where only one pass is required (as in the case using a portable ACFM system), and will not be missed. A key advantage is that ACFM scans are stable readings when used by trained operators. A key finding demonstrates the average depth measurement difference was 0.063 inches (1.6 mm) for ACFM findings and the grind-out results provided by the site. The internal consistency was made.

There are challenges given the nature of real world cracks in coke drums. ACFM only works on surface-breaking flaws. This is important to note as cracks tend to close up and so may present as a series of small, surface-breaking anomalies with no apparent depth. ACFM may not be able to detect such flaws. This brings up the question of how it compares to other NDE techniques.

ACFM scans are available for review and further interpretation after the scans are completed. The minimum detectable size is cracks larger than 0.75 inches (19.0 mm) long by 0.10 inches (2.54 mm) deep. During the field trial, other than very short length (< 0.4 inch (10.2 mm)) flaws, no defects were missed. Some shallow defects were reported where no LDP was present. One defect was 0.084 inches (2.13 mm) due to its proximity to a repair.

Another interesting finding was that ACFM only works on surface-breaking flaws. In coke drums, this is important to note as cracks tend to close up and so may present as a series of small, surface-breaking anomalies with no apparent depth. ACFM may not be able to detect such flaws. This brings up the question of how it compares to other NDE techniques.

Summary:

Using NDE, inspectors need be assured that no flaw over 0.75 inches (19.0 mm) long by 0.10 inches (2.54 mm) deep is missed. ACFM only works on surface-breaking flaws. This is important to note as cracks tend to close up and so may present as a series of small, surface-breaking anomalies with no apparent depth. ACFM may not be able to detect such flaws. This brings up the question of how it compares to other NDE techniques.
APPLYING ACFM TO A COKE DRUM

Key Factors:

- Remotely deployed service used to quickly verify the nature of surface breaking cracks
- Designed for online use, no need for scaffolding, removal of insulation or surface preparation
- Optimized for detecting indications extending beyond the clad
- Ideally suited for mid-life drums, works over coke cover, possible transition zones of metal overlay
- Used in combination with CIA’s laser/video inspection service to pre-identify high-risk regions
- Results typically provided within two weeks of inspection date
TYPICAL FINDINGS OF AN ACFM INSPECTION

2015 Sample
COKE DRUM MANAGEMENT THROUGH KNOWLEDGE

Laser Profiling:
- Tracking & Trending
- Cone Mapping
- Thermal Bowing or “Banana Effect”
- Enhanced Bulge Analysis Calculation
- Real-time analysis and processing
- Data Mining & Predictive Tools

Hi-Definition Digital Visual
- Optimized examination of most problematic and high-risk regions

Robotic Crack Detection:
- ID crack confirmation and measurement (length and depth)

Other Services:
- Pre-Turnaround Vessel Assessment
- External Structure Scanning
- Baseline Examinations of New to Service Vessels
- High-density scanning
- Operational Assessment

Important Partner in any long-term reliability program:
- Engineering Analysis
- Fitness for Service, Remaining Life
- Health Monitoring Systems
- Strain Gauge Instrumentation
- Weld Repair Strategies
CASE STUDIES

CIA presenter to discuss various case studies in which CIA’s service and approach has benefited major Indian / global refiners
IN REVIEW - YOUR FULL SERVICE PARTNER

✓ Technically superior service, best in class remote visual inspection, highest quality data, analysis & reporting available, and post-inspection support.

✓ The first step in the process towards a coke drum reliability program for improved performance, operator safety, asset life.

✓ Continues to innovate and introduce value add services & solutions to provide refinery operators the information they need.

✓ Strong commitment to continuous improvement to provide the most comprehensive and cost effective service possible.

✓ Partnerships with other world leading service providers to the Delayed Coking Industry to deliver additional value and benefit.

✓ The goal is to be **Proactive** on issues affecting drum integrity rather than being **Reactive** to the resulting problems that are inevitable.

✓ As the industry strives to better understand drum condition and repair strategies, CIA is extremely well positioned to assist each step of the way.
THANK YOU!

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