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Coke Drum Laser Profiling

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ABSTRACT

Coke drums are vessels in refineries that produce coker gas oil and petroleum coke. Typically the drums work in pairs: one drum operates at elevated temperatures while solidified coke is emptied from the second one. The process results in severe thermal cycles that over time cause distortion, cracking and other drum damage. Regular inspections are needed to ensure the drums are operating safely and to avoid unscheduled repair outages. Laser profiling inspection provides drum radius and position data that is used to produce colour coded maps of the drum’s inside diameter. The maps show bulges and other distortions and they are used for fitness for service (FFS) assessments.

This paper describes an advanced method being used now for rapid and accurate laser coke drum profiling. Previous laser profiling equipment required transit through the coke drum to obtain the radius measurements necessary for FFS assessments. Now, using more advanced laser technology with 3D imaging software, transit through the drum is not required. Laser results will be given for standard coke drum configurations showing the profiling detail possible. Also, the application of this laser profiling to other equipment will be shown.

Keywords: NDT, Inspection, Laser, Coke Drum, Fitness for Service.
INTRODUCTION

Coke drums are typically large vessels with diameters of roughly 20 feet (6 m) and heights up to 100 ft (30 m). Delayed Coker operations produce severe thermal cycles resulting from the heating of the vessels and then rapid quenching to allow removal of the coke. Over time, temperature cycling causes distortions, cracking and other damage to the vessel, often in the weld zones. Regular inspections are needed to ensure the drums are operating safely and to avoid unscheduled outages for repair work.

COKE DRUM LASER INSPECTION

Coke drum welds are susceptible to cracking, so inspection is typically done from the OD for detection of weld cracking. This is done using combinations of PAUT (phased array ultrasonic testing), TOFD (Time of Flight Diffraction) and rastered shear wave inspection. Typical requirements are to be able to detect small surface breaking ID cracks initiated in the HAZ (heat affected zone) of welds before they grow to a depth that is dangerous for service. Coke drums are usually internally clad, so scanning is generally carried out from the outside.

![Fig. 1: Colour Palette for Laser Radii Data.](image)

Thermal cycling also results in distortions in the overall drum shape, and inspection of the drums for bulging and/or other distortions is needed to ensure safe operation of the vessel. This inspection is typically done from the ID of the vessel, either between coking cycles or when the drums are down for scheduled maintenance, and consists of two parts.

![Fig. 2: Bulge Map of a Coke Drum.](image)
The first part of the inspection involves introducing a rotating laser head into a coke drum that traces a helical path from the top to the bottom head to shell welds. This is done by lowering a cable loop into the drum, which is extended from the top flange to the bottom flange so that a fixed reference line is established. This cable is then used to hold the laser assembly as it traverses the coke drum. Radius measurements of the ID surface of the drum are taken at an appropriate grid size to properly resolve any bulging in the coke drum.

As shown in Figure 1, a colour palette is used to visually display coke drum radius, much like an ultrasonic C-scan. Figure 2 shows a typical bulge map of a coke drum, where the entire vessel is shown in a rolled out view. Figure 3 is a polar plot of the coke drum data from Figure 2 at an elevation of 596 inches from the bottom flange, and it shows asymmetry in the radius at this elevation. Figure 4 shows a vertical cross section of the coke drum data from Figure 2 at an azimuth of 307°, and it shows a number of bulges between the elevations of 340 and 640 inches.

Fig. 3: Polar Plot of Coke Drum at Elevation 596 Inches

Fig. 4: Vertical Cross Section of Coke Drum at Azimuth 307°.

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Bulged areas are evaluated using a BSR (bulge severity rating), as shown in Equation 1, where the depth and length are determined for each bulge using the laser data. A value of $BSR = 0$ corresponds to a location with no bulging, and a value $BSR=1$ corresponds to a bulge that is as deep as it is long. This provides customers with a quantitative measure of the severity of bulging in their coke drums, is used for trending bulge growth over time, and it can be used along with radius measurements for FFS (fitness for service evaluations).

$$BSR = \frac{\text{Depth}}{\text{Length}}$$

The second part of the inspection is done with a high resolution video camera to image the ID surface of the drum for detection of cladding damage. The camera is attached to the same cable that is used for the laser inspection, and it is capable of rotating 360°, tilting 240° and zooming up to 24 times. High-resolution video is included in the report. Typically, all circumferential and select vertical weld seams are observed during this inspection. Figure 6 shows a video capture of an area on the ID cladding of a coke drum with cracking.

**Fig. 6: Video of Cladding Cracking.**

NEW COKE DRUM LASER SYSTEM

IRISNDT has recently introduced a new laser mapping system into the market that is a significant advance over previous technology. This capability uses high resolution laser systems that are able to map out large areas on variable grid sizes. This system is introduced into a coke drum from either the top or bottom flange, and it is stabilized using gyroscopes. It is then programmed to capture point cloud data of the ID surface of the drum. In some cases the data can be captured with one scan, but more commonly multiple scans are required to provide high enough resolution data for quantifying bulges. When more than one scan is done, they are combined to form one point cloud of the coke drum.

This data is then exported to software that is able to take point cloud data and apply a triangular mesh to form a surface representing the coke drum. Once the mesh is generated, there is much flexibility to generate vertical cross sections, horizontal cross sections or deviation maps of bulged areas. Colour is used to denote the deviation from a reference model, often an ideal cylinder of the correct dimensions. For standard colour palettes, red corresponds to an outward bulge and blue to an inward bulge. Mesh data is well suited for export to finite element modeling programs for fitness for service evaluations, and also for export to fabricators for proper preparation of patch plates when repairs are being done.
Figure 7 shows a typical deviation of a coke drum with bulged areas. There are four separate smaller figures that correspond to the four sides of the coke drum; north, south, east and west. The colour palettes have been chosen to scale properly with the extent of bulging present in this coke drum. The grey colour at the top and bottom correspond to radii on the coke drum that are outside the range of the colour palette chosen for this display. There are typically radius laser data for the top head and bottom cone section gathered during the data acquisition process, but it is usually not displayed for bulge analysis. The line graph and percentage values correspond to the histogram of data points within the colour palette divisions.

**Fig. 7**: 3D Mesh of Coke Drum.

**OTHER LASER INSPECTION APPLICATIONS**

The basic capability of the laser systems and associated software to accurately map surfaces has more applications in the industrial NDT field than just coke drum inspection. This system is currently being used for storage tank mapping. Figure 8 shows raw point cloud data from a tank inspection, which is later rendered into a mesh for determining bulging, deformations, tank volume, etc. Full surface mapping of tanks is typically more complicated than coke drum
inspection due to the myriad of obstructions inside the tank requiring multiple laser scans that are combined together.

![3D Point Cloud Data for a Storage Tank.](image)

**Fig. 8**: 3D Point Cloud Data for a Storage Tank.

The other application that IRISNDT is using the laser technology for is mapping external corrosion on piping and pressure vessels. Figure 9 shows the data from an external corrosion inspection on 6 inch diameter piping, where the colour palette shows deviation from an un-corroded OD surface. In this case, the maximum depth of pitting is 0.118 inch from a nominal wall thickness of 0.300 inch.

![OD Pipe Corrosion.](image)

**Fig. 9**: OD Pipe Corrosion.

**CONCLUSIONS**

This paper has presented a new laser mapping system that is being used for accurate and rapid dimensional measurements and high resolution video mapping. This capability replaces a previous system that required traversing the coke drum on tensioned cables, and represents a significant reduction in cost to the customer with an improvement in data quality. This laser mapping capability is also being used for other industrial equipment, such as tanks and piping.