Diametric growth detection

on reactor charge heater radiant tubing

Merlin INSPECTION TECHNOLOGY

BACKGROUND

Cokebusters USA Inc. was contracted by a client to carry out a Merlin™ in-line inspection of a Reactor Charge Heater as part of their scheduled maintenance turnaround in 2014. The inspection was carried out using the patented Merlin™ "Smartpigging" system for accurate geometric assessment of both convection and radiant coils in four separate passes. Prior to inspection, the process coils were thoroughly decoked and cleaned internally, using Cokebusters mechanical pigging system. The complete operation for the full decoke and inspection works took approximately 36 hours from start to finish, including rig/de-rig times.

MERLIN MARK IV INSPECTION SYSTEM

The **Merlin Mark IV Smartpig** is a carbon fibre, single bodied un-tethered device, which employs a series of ultrasonic transducers to measure tube wall thickness and internal radius at equally spaced circumferential locations along the full length of the heater coil, effectively scanning the process tubes for geometric abnormalities or defects. The smartpig records and stores the received data to its on-board memory, which is later uploaded via USB to a computer. The data is then automatically interpreted and analyzed by the Merlin™ software, which can then output various graphical images and C-scans of the process tubes.

The Smartpig itself is constructed from a neutrally buoyant, moulded carbon fibre body, the interior of which contains the electronic circuitry, and lithium-ion battery back. The microprocessor manages the operation of the whole device, including data acquisition, sorting and storage. The battery pack is capable of achieving a run time of up to 8-hours before a recharge is necessary.

The scanner unit employs a series of custom built piezo-composite transducers, each constantly firing and receiving a complexity of rapid-fire ultrasonic pulses. The moulded body is encased in a separate Carbon Fibre/HDPE/Kevlar framework for protection and propulsion through the furnace tubes. This complete unit is able to be driven bi-directionally through tight radius tube coils under water pressure supplied by the same pumping unit as used for mechanical decoking.

INSPECTION RESULTS

Significant diametric abnormalities were identified within the radiant coils of passes 1, 2 and 3. These abnormalities were more abundant in Pass 2, with diametric growth up to 4.7% (Pass 2, Tube 7) observed. This phenomenon was clearly visible in the 3D C-Scan and accompanying graphical plots (Figures 2, 4(a) & 4(b)). The diametric anomalies were considered to be "irregular" due to the consistent swelling around the full circumference of the tubes, as opposed to ovality or localized bulging on the fire side of the pipe-work. The tube wall thickness was seen to be constant throughout the radiant tubing, with minimal deviation from the nominal value. This can be seen in the graphical plot shown in Figures 3 and 4(c).

Figure 1: Merlin Mark IV SmartPig

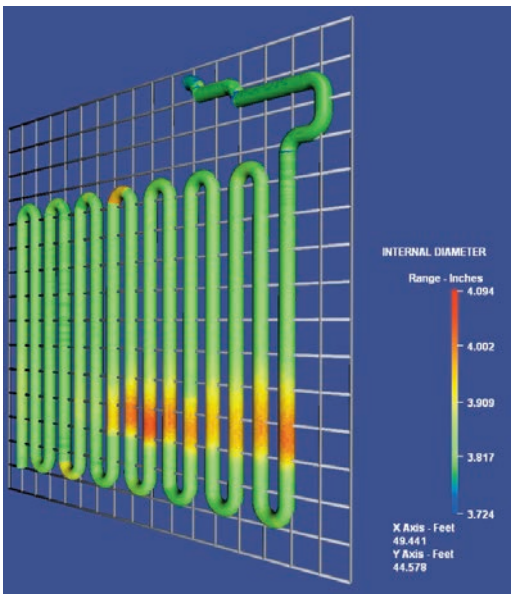


Figure 2: Pass 2 Internal Diameter 3D C-Scan showing diametric growth in Radiant Coil 2

FAILURE MECHANISM

Following the inspection, a full Level III Fitness for Service assessment was carried out in accordance with API 579-1/ASME FFS-1. Visual examination, microstructural analysis and micro-hardness measurements were conducted on the heat affected areas. Scanning Electron and Optical microscopy confirmed the presence of ferrite and martensite in the heat affected areas, indicating that the tubes were exposed to skin temperatures in excess of 750°C, with a high rate of cooling experienced. The micro-hardness measurements obtained in these areas further confirmed exposure to excessive temperatures and were attributed to strain hardening resulting from plastic deformation from exposure to elevated operating temperatures and pressures. Overheating reduced the tube strength sufficiently that the internal stresses exceeded the yield strength of the tubes, which ultimately led to diametric swelling. Upon discussion with the client, it was concluded that the radiant tubes were subjected to short-term overheating during operational shutdown, which ultimately led to the tube bulging and diametric deformation within the radiant tubing. Long-term creep damage was ruled out due to the uniform concentric swelling, accurate burner alignment and known historic operating temperatures outside of the creep regime.

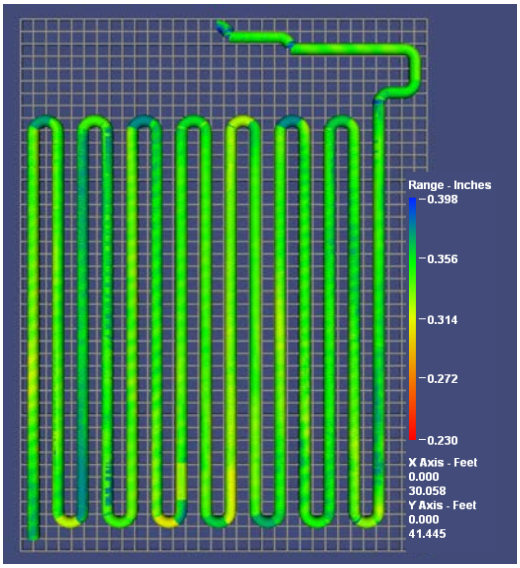
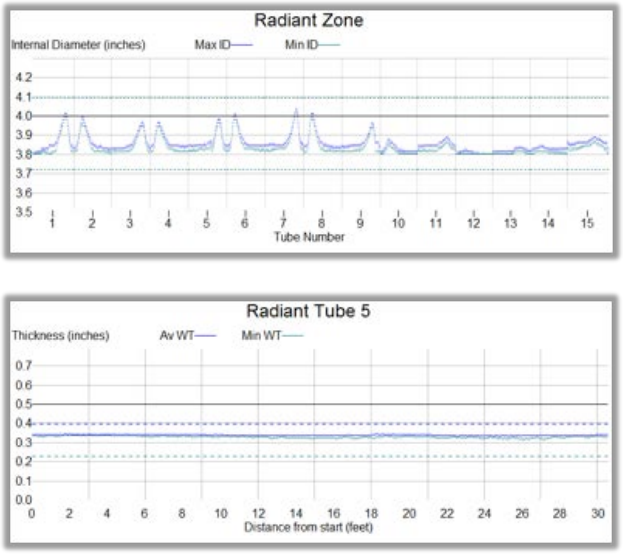


Figure 3: Pass 2 Wall Thickness C-Scan

CONCLUSIONS

Following the Inspection, the tubes that were identified as damaged were removed upon Cokebusters advice. All defect quantification and location was confirmed by the client, who remarked that this damage would almost certainly have gone undetected using conventional NDT methodologies.

Annual mechanical decoking and smartpigging operations have since been introduced into all of the client's future turnaround schedules for this heater.



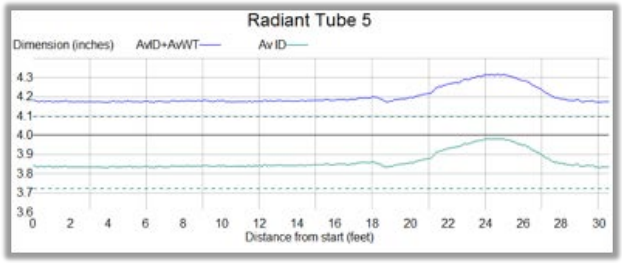


Figure 4: Graphical plots showing (a) Diametric increase in Radiant Tubes 5-9 (Inclusive), (b) Average diametric growth in radiant tube 5 and (c) Wall thickness profile along radiant tube 5

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