CIA Inspection (US), Inc.

COKE DRUM LIFE IMPROVEMENT
A COMBINED APPROACH

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Today's Presentation

Distortion Monitoring
Remote Internal Visual Inspection

Coke Drum Management Through Knowledge

Strain Gage Measurement
Acoustic Emission Testing
Owner/Operator’s Dilemma

- How to:
  - manage capital asset in responsible and cost effective manner
  - optimize process control to maximize throughput
  - improve reliability and reduce maintenance costs
  - maximize drum life
  - effectively plan for vessel replacement

Coke Drum Design

- Typically designed and built to the ASME "Boiler and Pressure Vessel Code" Section VIII, Division I
- Generally not designed for low cycle fatigue
- Traditionally designed with horizontally-arranged courses varying in thickness from bottom to top
Coke Drum Realities

- Drums operate under severe conditions of cyclic heating and forced cooling
- Variable nature of the process results in a wide variety of experiences for drums of similar design

Coke Drum Failures

- Ultimate failure mechanism is crack initiation in plate-plate welds due to low cycle fatigue
- Almost all cracking occurs on circumferential welds
- Drums fail in a leak-before-break failure mode
Through-wall Crack

Extensive through-wall cracking started from inside

Coke Drum Inspection/ Monitoring

- Most direct method of crack determination:
  - Visual or dye penetrant inspection from inside
  - Ultrasonic inspection from outside
- Impractical to perform 100% inspection
- Predictive/preventive approach must be utilized
Coke Drum Inspection/ Monitoring

- Distortion Monitoring
- Remote Internal Visual Inspection
- Strain Gage Measurement
- Acoustic Emission Testing

Distortion Monitoring

- Remote laser surface profiling performed between cutting and refilling
- Laser based range imaging system collects laser distance measurements of entire vertical surface of vessel
- Color contour map shows bulge profiles and other distortions
- Allows drum comparison over time
- Custom designed software "Drumview" interprets the drum scan data
Distortion Monitoring

- Regular laser profiling of coke drums allows operators to:
  - Focus further inspection efforts on welds near deformed areas
  - Compare degree of deformity among their different drums
  - Compare change in drum deformities over time
  - Compare site specific results with industry wide trends
  - Model effects of a typical quench cycle using finite element modeling tools

Typical Bulge Maps

Mid Life Drums
Remote Internal Visual Inspection

- Remote video inspection performed between cutting and refilling
- Color video camera with a high resolution zoom lens used to identify surface flaws
- Videotape registered with same elevation and azimuth as laser scan
- All findings recorded on VHS tape and documented and reported by API certified inspector in report format
Visual Inspection Findings

Visible crack in circ weld

Cladding failure

Cladding repair

Crack in overlay
Further Monitoring

- Depending on findings from laser & remote visual inspection, additional activities/approaches can be undertaken
  - Engineering analysis
  - Materials evaluation and testing
  - On-line monitoring of damage
  - Fitness for service
  - Operational control and optimization
  - Recommendations on repair/replace procedures

Strain Gauging

- With Stress Engineering:
  - Use laser image dimensions to properly place strain gauges in areas of most stress/strain
  - Data provides complete corrections to strains from temperature-induced error, calculation of bi-axial Principal Stress results, including Stress Intensity
  - Extrapolations made from database to predict remaining useful life of drum
Strain Gage Monitoring

Strain Gage Locations on Shell
Strain Gage Locations at Skirt

Output from Strain Gage Measurement

- Operational intelligence to reduce fatigue damage
- Fatigue crack growth prediction
- Low cycle fatigue damage accumulation
- Remaining life assessments
Dimensional Assessment for Replacement

- With CB&I:
  - In conjunction with laser inspection dimensional data can aid in the correct custom can replacement
  - Drumview "export" feature can help manufacture proper fit-up - bulging and ovality
  - New coke drum inspection to meet code qualifications

Improved Replacement Techniques

- Replacement Scenarios
  - A section of vertical wall
  - The cylindrical portion of the drum
  - The entire drum

- Drum profile information helps:
  - to define location of section to replace as many bulged areas as possible
  - to define interface with remaining portion of original drum
Improved Replacement Techniques

Section of laser scan showing distortion at circ weld

Section of laser scan after repair showing location of "repair patch"

New Look at Coke Drum Design

- Design shell and skirt for low cycle fatigue
- Design using "actual" measured thermal transients, rates and strain ranges
- Utilize uniform thickness walls of high yield strength plate
- Match yields between plates and welds
- Flush grind weld caps
- Arrange course plates vertically
Weld Repair Plan & Procedures

- Develop repair and replace procedures for defective areas of coke drums
- Recommend correct inspection and repair techniques
- Provide on-site consultation and if necessary can provide supervised contract welders to ensure the best possible repair is performed using the correct procedure

Summary

- Coke drum life improvement is a combined approach
- CIA with alliance partners can help improve the reliability of your coke drums
- Improved reliability means improved profitability