PERFORMANCE OF ILI TECHNOLOGIES FOR DENTS WITH INTERACTING FEATURES

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This is an overview of the PRCI NDE-4-18 project, part of the PRCI MD SRP

- To support industry drive for integrity management improvement
- PRCI sponsored these trials to consider ILI performance for mechanical damage (dents) with coincident features (corrosion, gouge, crack)
- Consider a range of ILI technologies and systems

The objectives were to

- Prepare and characterize pipe samples with dents and coincident features
- Demonstrate performance of ILI technologies wrt feature detection, identification and sizing
- Provide feedback and reference data to Service Providers for system and specification development
• Trial Samples and Features
  • Focus on 20 inch diameter (ERW / DSAW) pipe
    • 0.25 to 0.5 in wall thickness
  • Features in current trials identified as
    • Dent
    • Corrosion in plain pipe
    • Dent with corrosion
    • Dent with gouge
    • Dent with cracks
    • Dent with corrosion and cracks
  • Approx. 500 ft of pipe with 65 dent features w/wo coincident features
Sample Production and Characterization

- **Sample Feature Production**
  - Dent features
    - Formed in lab with a range of indenters
    - Single and multi-peak dent shapes
  - Corrosion features
    - Pipe removed from service
    - Corrosion wall thickness reduction 10% to 40%
  - Cracks
    - Formed in dents by cycling pipe internal pressure
  - Gouges (EPRG provided)
    - Simulated during indentation with backhoe tooth
    - Machined on dent surface
Sample Production and Characterization

- Sample Characterization
  - Dent and corrosion features
    - Full circumference surface laser scan
      - Defines 3 dimensional shape of dent and corrosion features
    - Scan data confirmed with caliper & pit gauge
Sample Production and Characterization

- Sample Characterization
  - Crack features
    - Characterized digitally after magnetic particle inspection (MPI)
      - Defines surface length and position of features
    - Metallurgical sectioning and Computed Tomography (CT)
      used to augment crack depth and shape for a subset of features
Sample Production and Characterization

- Range of Corrosion Features
  - Considered features of various depth, length and width
  - All features identified based on API 1163 classes
    - Pin-hole
    - Pit
    - Axial / Circ. Groove
    - Axial / Circ. Slotting
    - Extended
Sample Production and Characterization

- Range of Dent Feature Shapes
  - Single and multi-peak dents with depths ranging from 1 to 5% of pipe dia.
  - Dents created with various indenters with pipe unpressurized and pressurized
Trial Protocol

- Document developed describing the trial process
  - Two repetitions of five test speeds (1.1, 3.3, 5.6, 7.8 & 11.1 mph)

- Define feature specific data reporting
  - Seven specific features types defined
    - Crack in corrosion
    - Crack in corrosion in dent
    - Crack in dent
    - Corrosion in dent
    - Corrosion
    - Gouge in dent
    - Dent
  - Characteristics of each feature and position defined relative to reference mark
  - Dent coincidence zones defined
  - POD and POI defined statistically as in API 1163

- Trials completed for seven ILI Service Providers
Trial Protocol

- Corrosion feature matching
  - No clustering or boxing of features considered because rules not standard
    - Resulted in higher POD for larger features
    - Resulted in low POI for larger or longer features
• Dent depth unity plot performance for all tests of one ILI system
  • Good overall performance
  • Most data within 4 mm of reference
    • Unity line 2 and 4 mm arbitrarily selected (not standard)
  • Small bias to call out deeper dents
  • Small amount more variability in U/S measurement
Trial Observations and Performance – Dent Depth

- Dent depth unity plot performance for all tests of six mechanical caliper ILI systems
  - Approx. 6,300 observations
  - Good overall performance
  - Most data within 4 mm of reference
    - Unity line 2 and 4 mm arbitrarily selected (not standard)
  - Small bias to call out deeper dents
  - Small amount more variability in U/S measurement
- Ultrasonic caliper system displayed similar performance
Dent characteristic length unity plot performance for all tests of one ILI system:
- Good overall performance
- More variation at dent shoulder (10% max depth)
- Small bias to call out smaller lengths
- Small amount more variability in D/S measurement
- CW and CCW results the same
Trial Observations and Performance – Corrosion

- Unity plot for all non coincident corrosion features of one ILI system
  - Good overall performance on depth
  - Small bias underestimating feature depth
  - Bias to underestimate length of long features
  - Bias over estimate width of features
Trial Observations and Performance - Corrosion

- Unity plot for all dent coincident corrosion features of one ILI system
  - Good overall performance on depth
  - Small bias underestimating feature depth
  - Bias to underestimate length of long features
  - Bias overestimate width of features
Similar performance observed for six magnetic ILI systems

Ultrasonic tool provided the same performance
• Corrosion POD performance effect of dent coincidence for one ILI system
  • No significant impact of dent on POD
  • In future, will consider as a function of dent depth
Corrosion depth sizing, effect of dent coincidence for one ILI system

- Small impact, if any, on average sizing variation
- In future, will consider as a function of dent depth
Effect of corrosion feature location on POD and sizing for an ILI system

- Small impact (peak zone most affected)

Trial Observations and Performance - Corrosion

- Effect of corrosion feature location on POD and sizing for an ILI system
  - Small impact (peak zone most affected)
Trial Observations and Performance - Gouges

- Effect performance on small pool of gouge features for one ILI system
  - Clock position not controlled
- Two types of gouges considered as provided by EPRG Project 217
  - Simulated – back hoe tooth formed
  - Machined – dented and machined
- Laser surface scan identifies features
- For six ILI service providers
  - High POD (>90%)
  - Simulated features POI (80%)
  - Machined features lower POI (67%)
- Significant error in gouge length
Trial Observations and Performance - Cracks

- Performance for Crack Features
  - Ultrasonic ILI tool
  - All features coincident with dent
  - Some features in corrosion
  - Good POD not sensitive to tool speed
  - POI includes identification of
    - Initiation surface
    - Orientation of the crack

![Crack Lengths Graph](Image)

![Tool Speed vs. POD Graph](Image)
Next Steps

• More work ongoing
  • Completion of the current work
    • Reporting to ILI Service Providers and Combined report (NDE-4-18)
  • Additional ILI performance trials
    • PRCI / US DOT PHMSA trials
    • 165 dents with corrosion, welds, cracks and gouges
  • Integrity management program enhancement
    • Performance for Detection, identification and sizing of cracks
    • Additional truth data (metallurgical sampling)
    • Catalogue samples at PRCI TDC for re-use
  • Improvement of ILI codes and standards
    • Provide information to support regulatory changed
    • Standards enhancement (e.g., API 1163 and API RP 1183)
Concluding Remarks

• Current work demonstrates
  • ILI trial program for mechanical damage with coincident features possible
    • Protocol and assessment procedures are good
    • Some opportunities for improvement
  • Performance of existing technology is good
    • Can detect, identify and size dents and corrosion
    • Can detect and identify gouges and cracks
      • Length sizing will improve as truth/reference data is shared
    • Shows promise to support fitness for purpose assessment of dents with coincident features

• Feedback to ILI Service Providers may support enhancements
  • Uniformity in reporting
  • Performance of ILI systems
Thank you for your attention.