EPRG-PRCI-APGA

23rd Joint Technical Meeting

Edinburgh, Scotland • 6–10 June 2022

PERFORMANCE OF ILI TECHNOLOGIES FOR DENTS WITH INTERACTING FEATURES

08 June 2022

# PRCI NDE-4-18 Project – Introduction

- 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
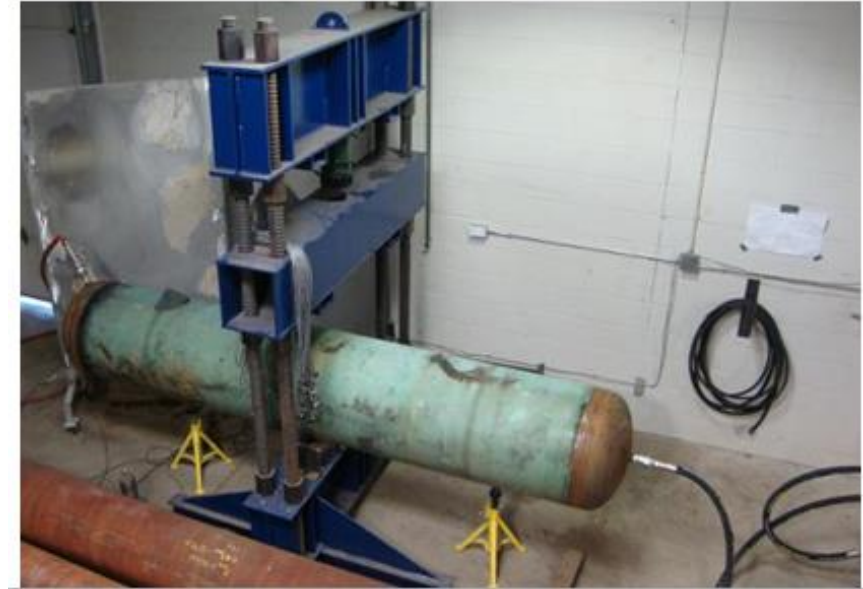
Sample Production and Characterization

- 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
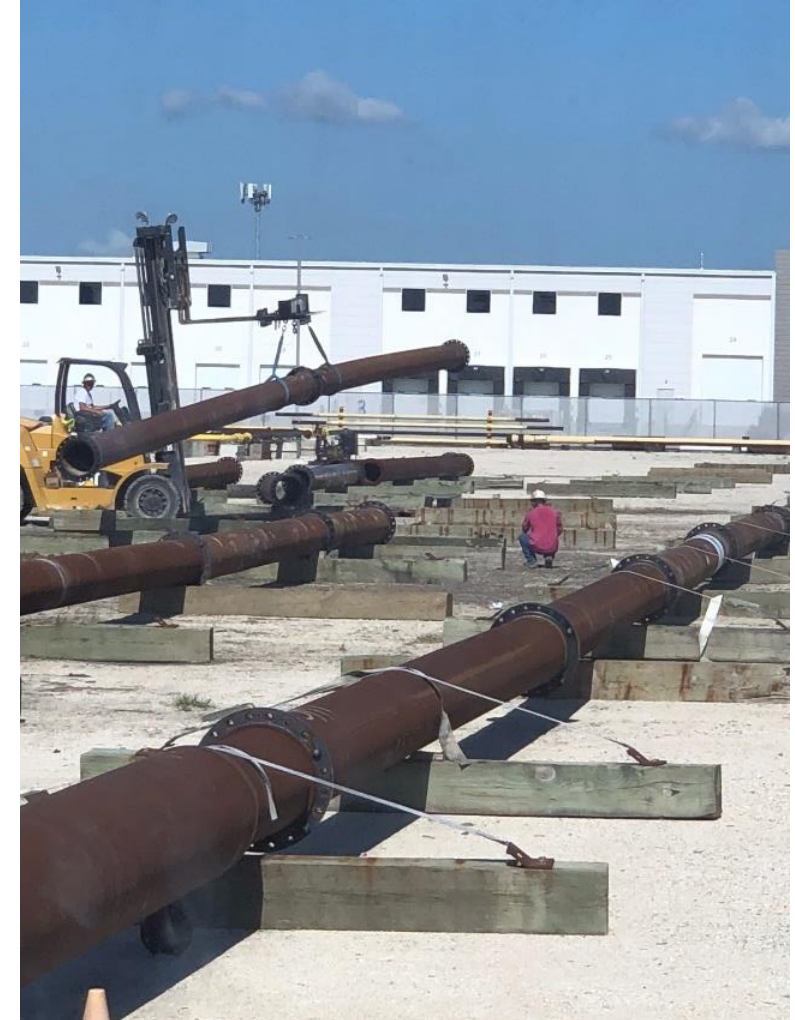
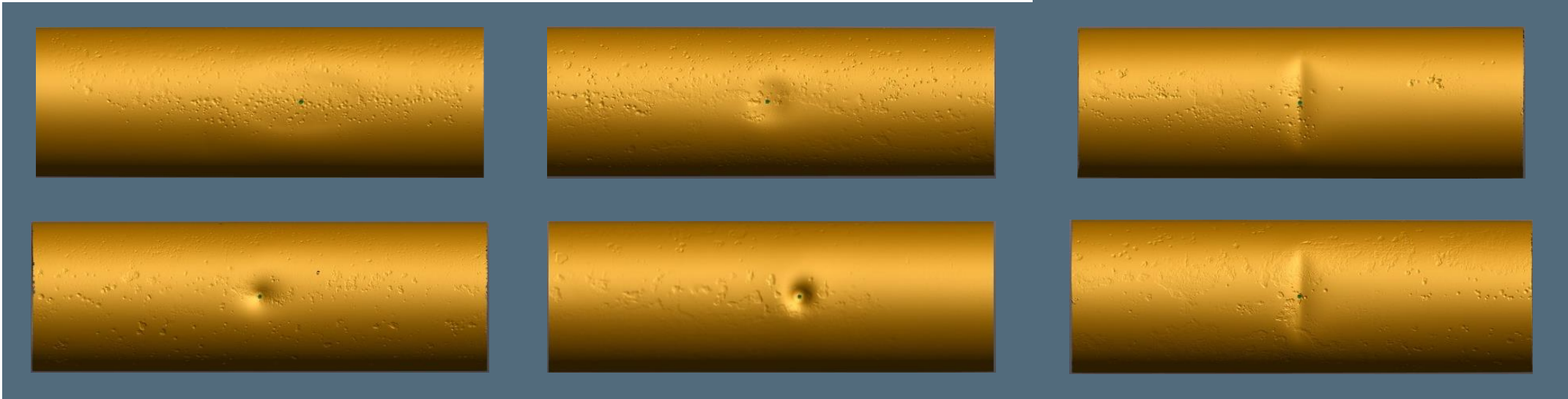# Sample Production and Characterization

- 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
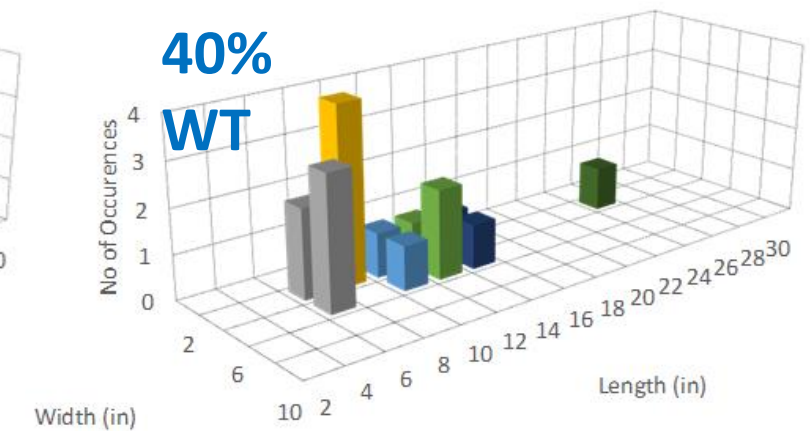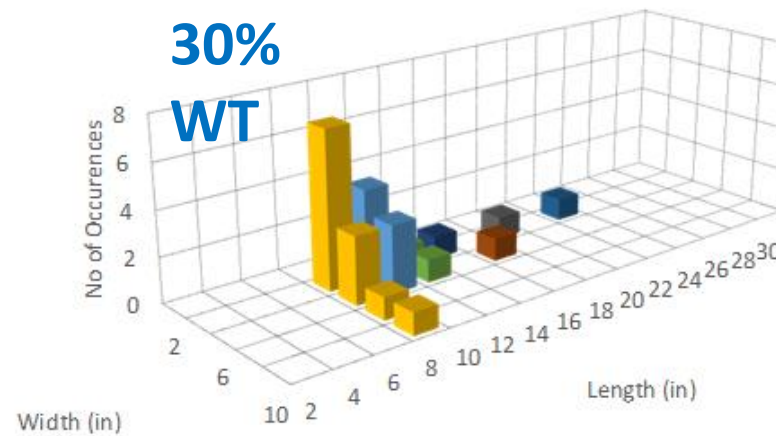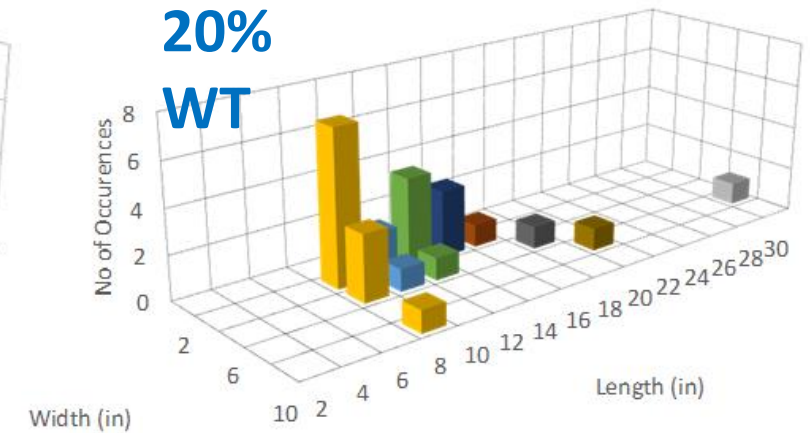
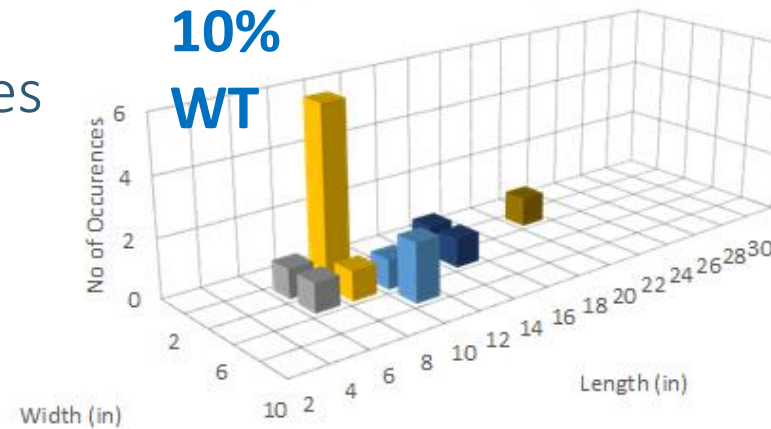# Sample Production and Characterization

- ## 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
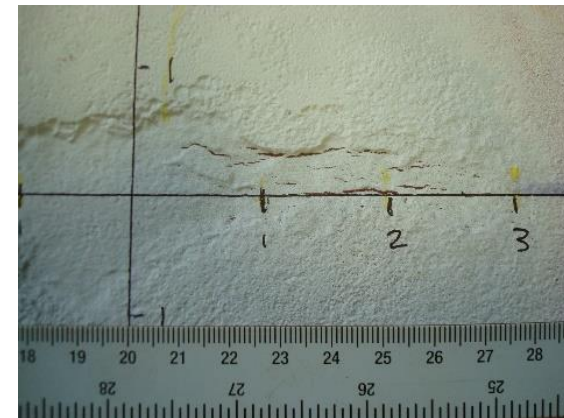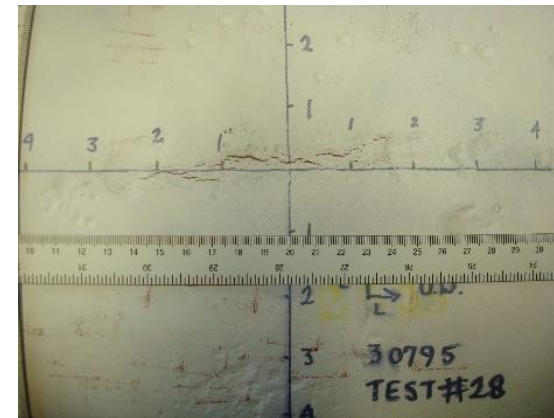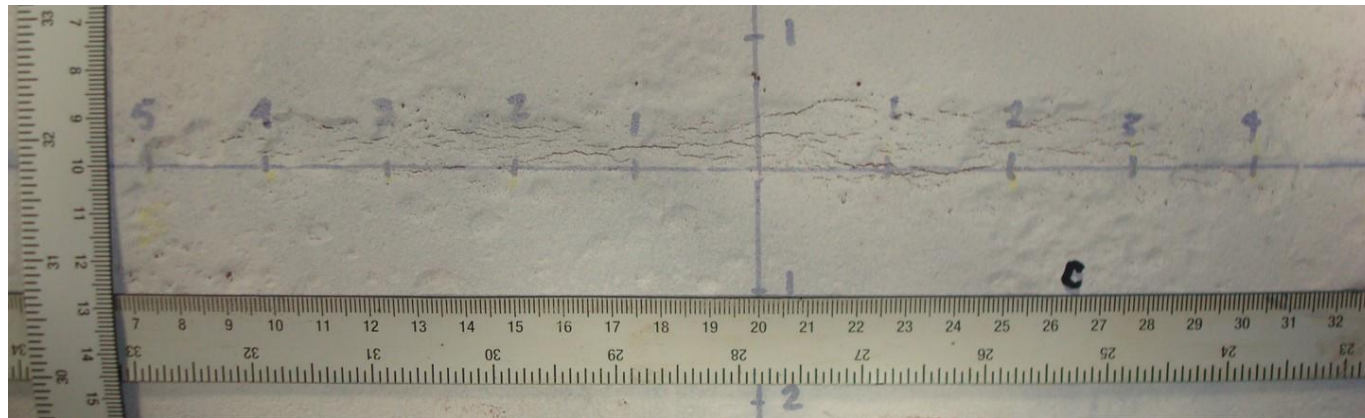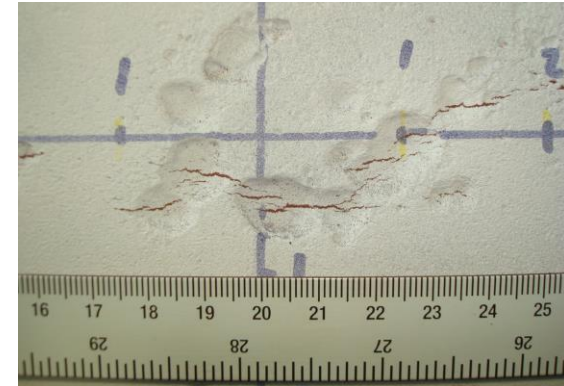
# Sample Production and Characterization

- 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

10% WT

20% WT

30% WT

40% WT

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
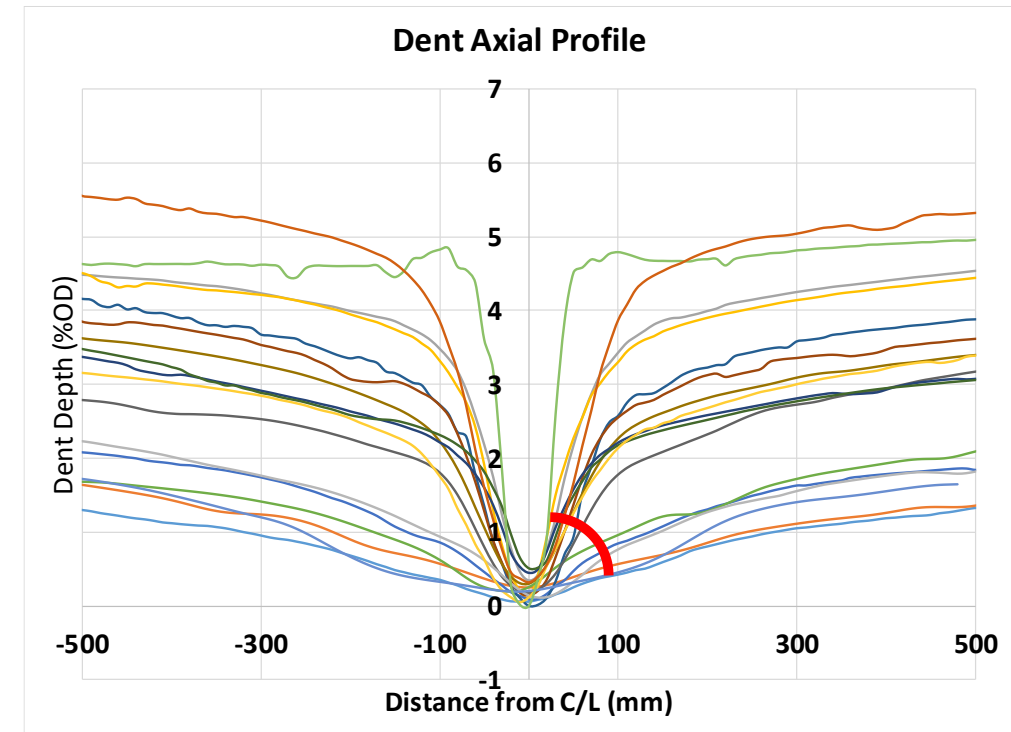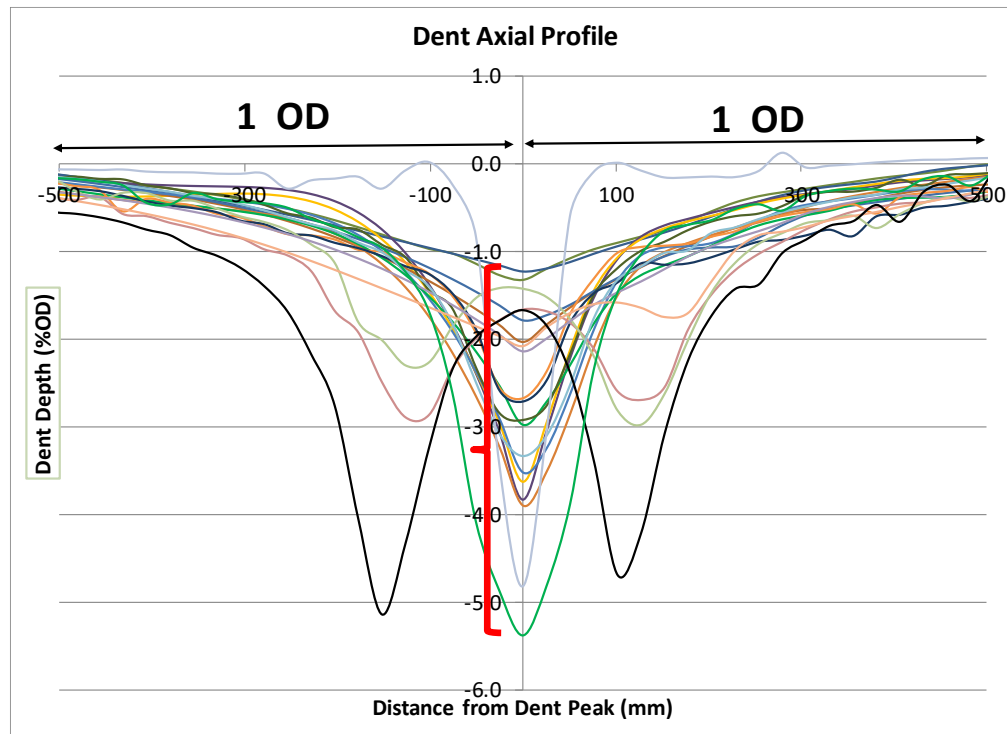
Trial Protocol

- 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 dent
    - Corrosion
    - Dent
    - Crack in corrosion in dent
    - Corrosion in dent
    - Gouge in dent
  - Characterstics 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
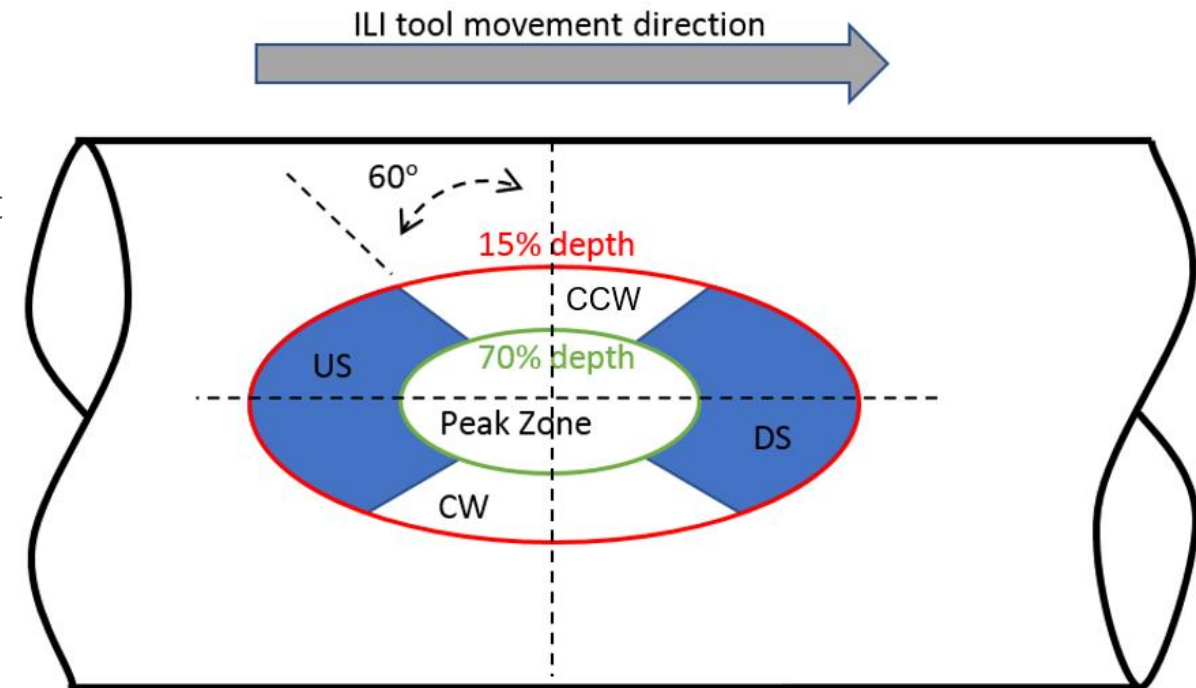
Trial Protocol

- ## 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
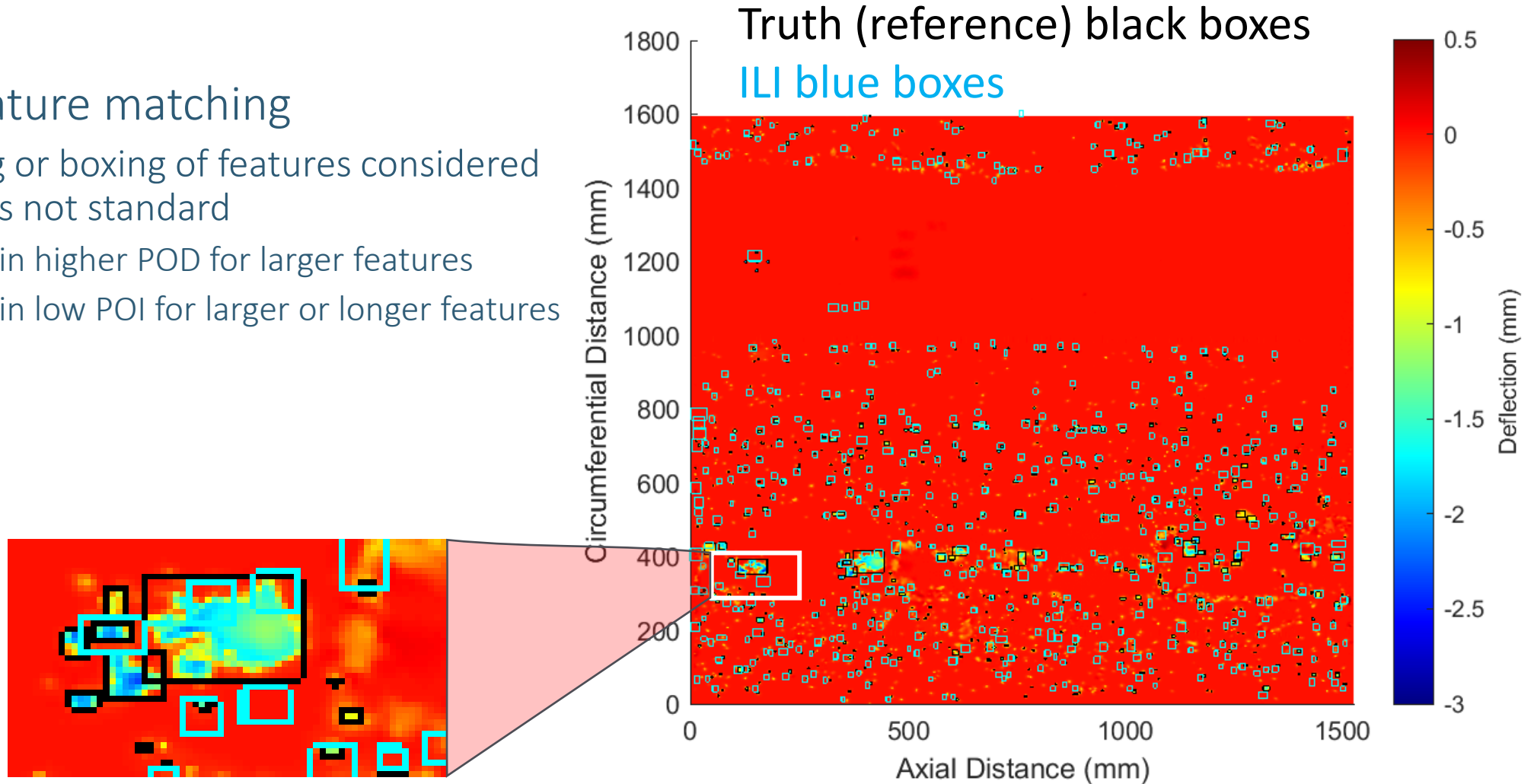
Truth (reference) black boxes
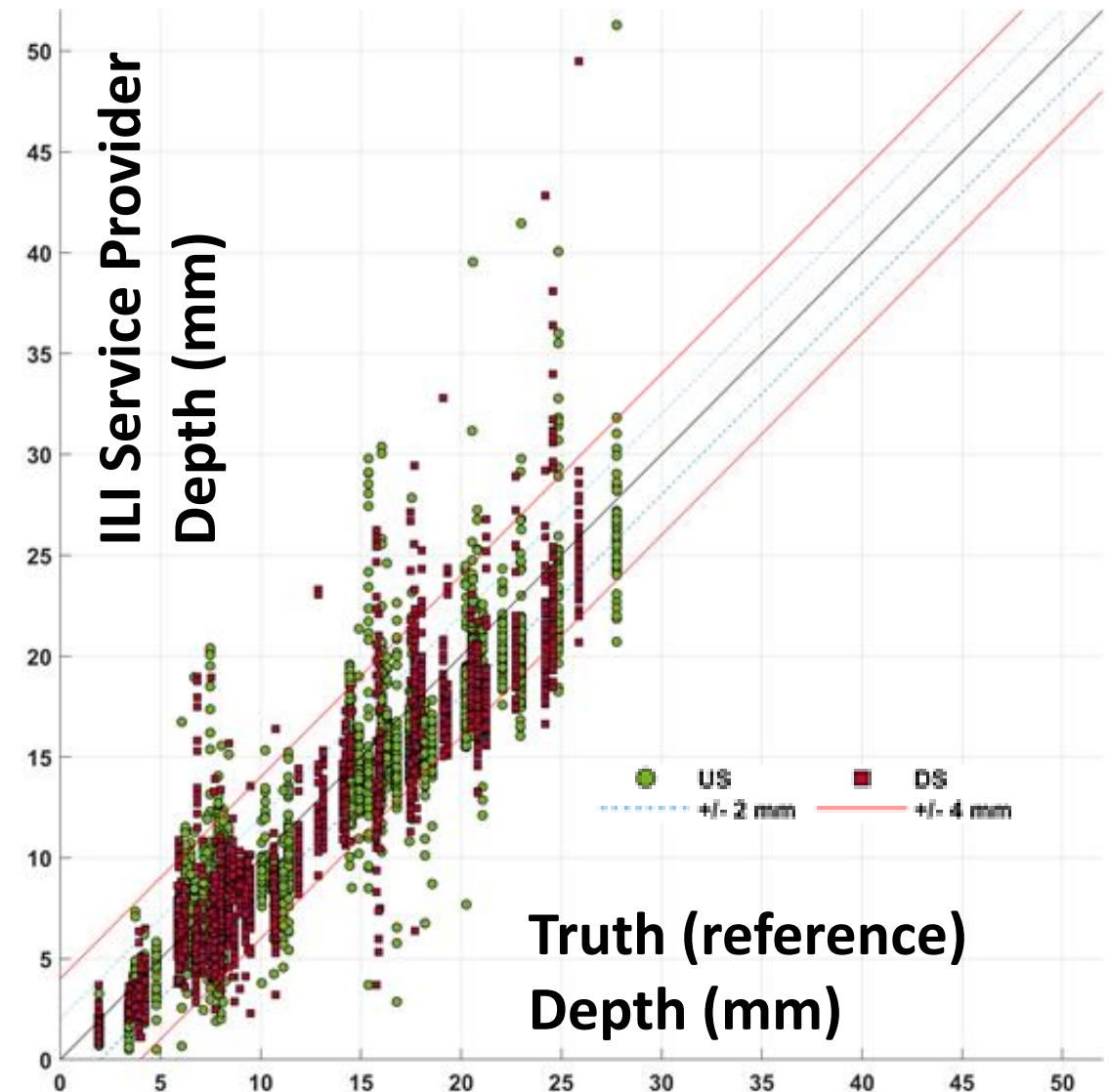
ILI blue boxes

Trial Observations and Performance – Dent Depth

- 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

All Pulls

ILI Service Provider Depth (mm)

Truth (reference) Depth (mm)

US   DS
+/- 2 mm   +/- 4 mm
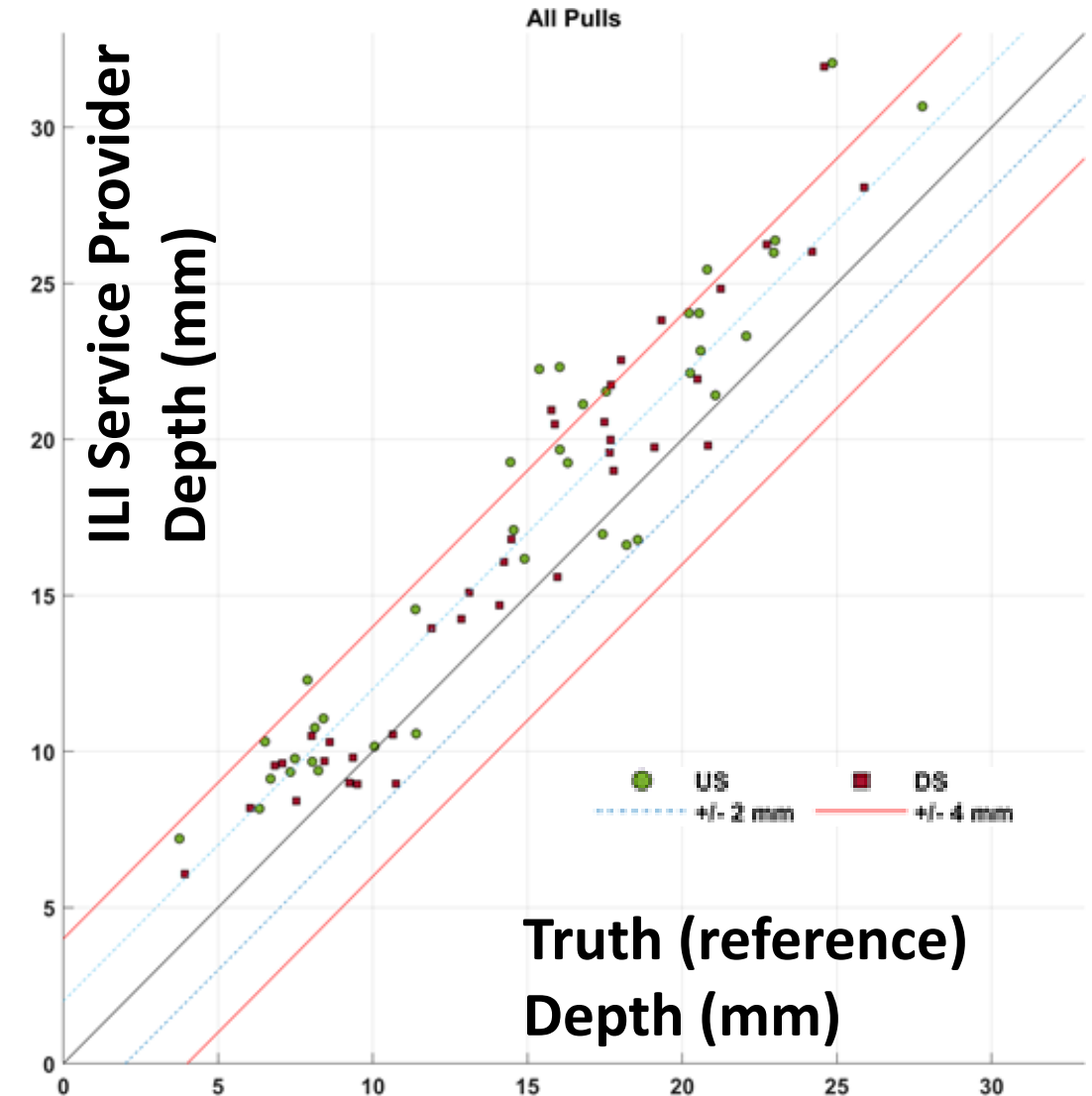
Trial Observations and Performance – Dent Depth

- 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

Trial Observations and Performance – Dent Shape

- 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
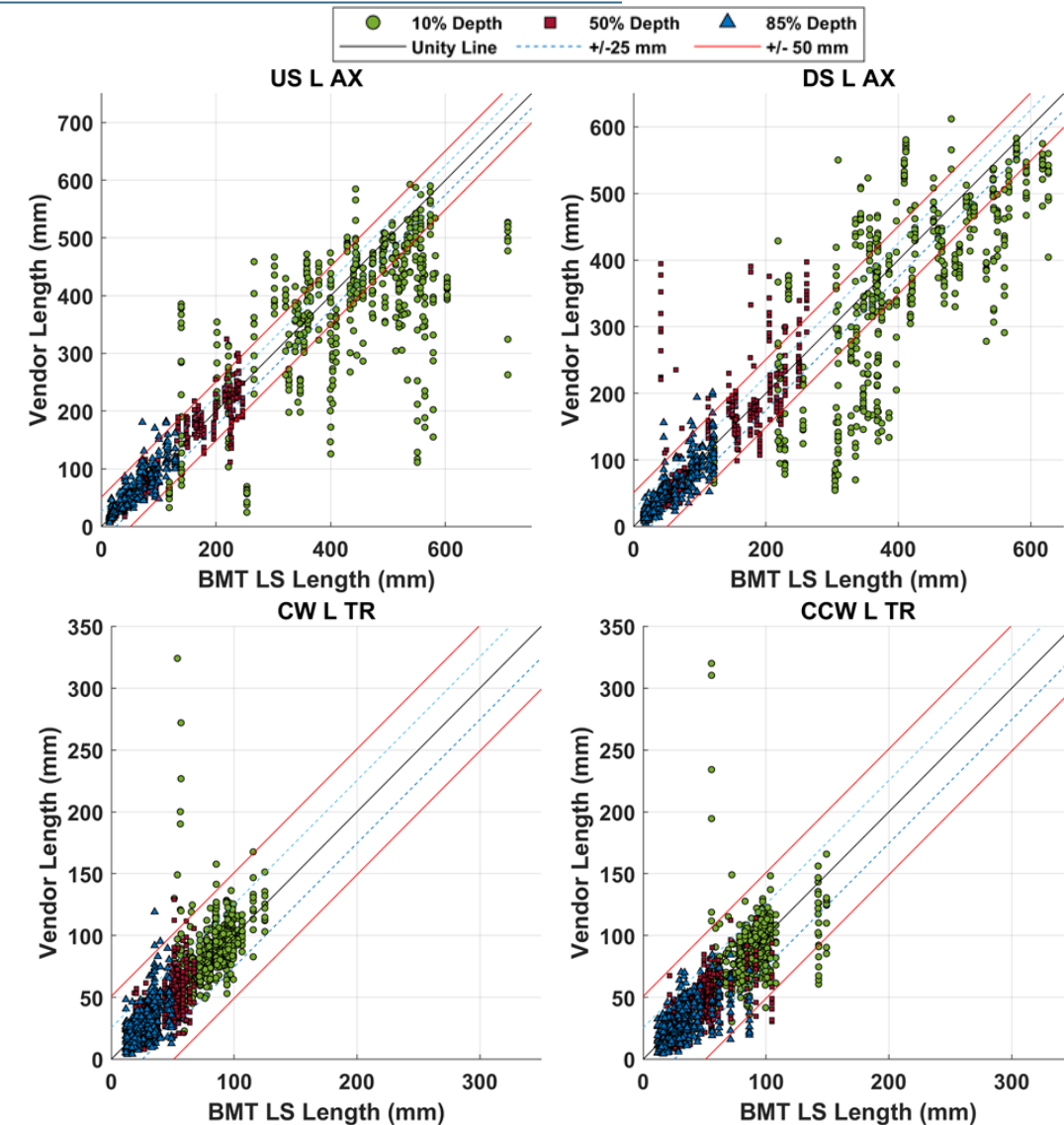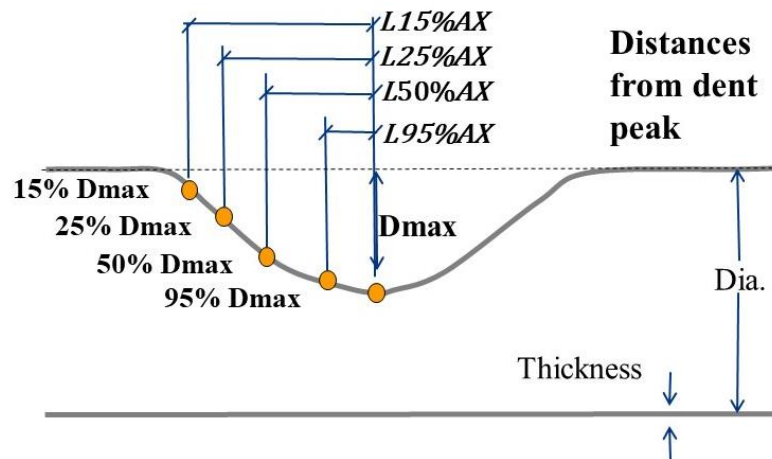
Trial Observations and Performance – Corrosion

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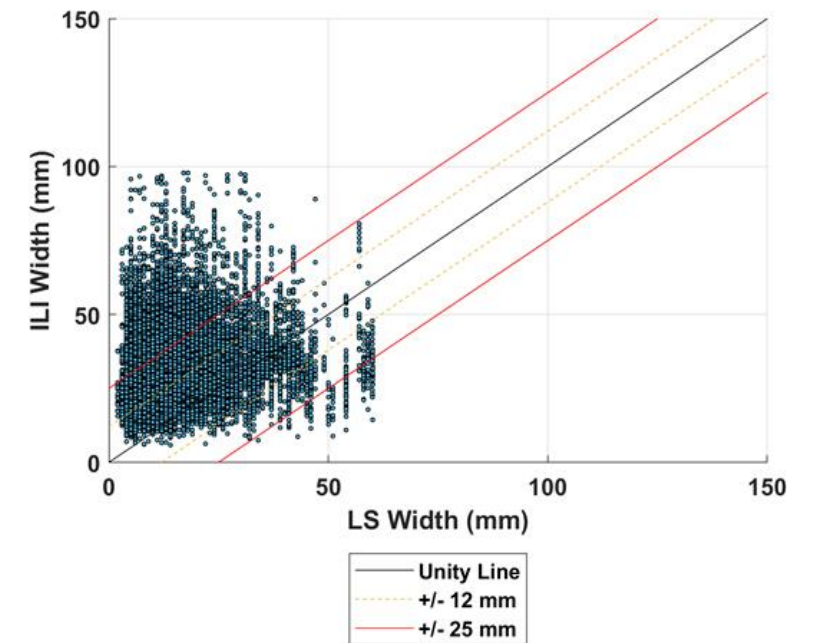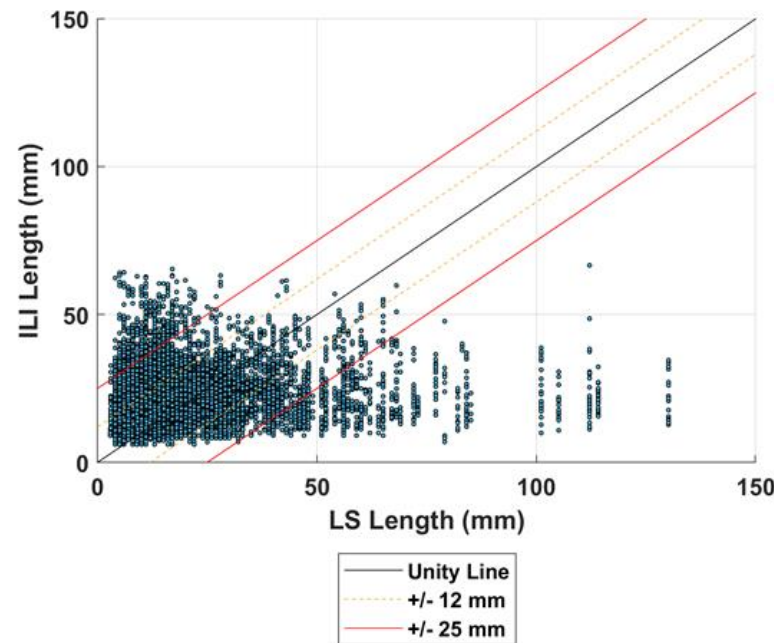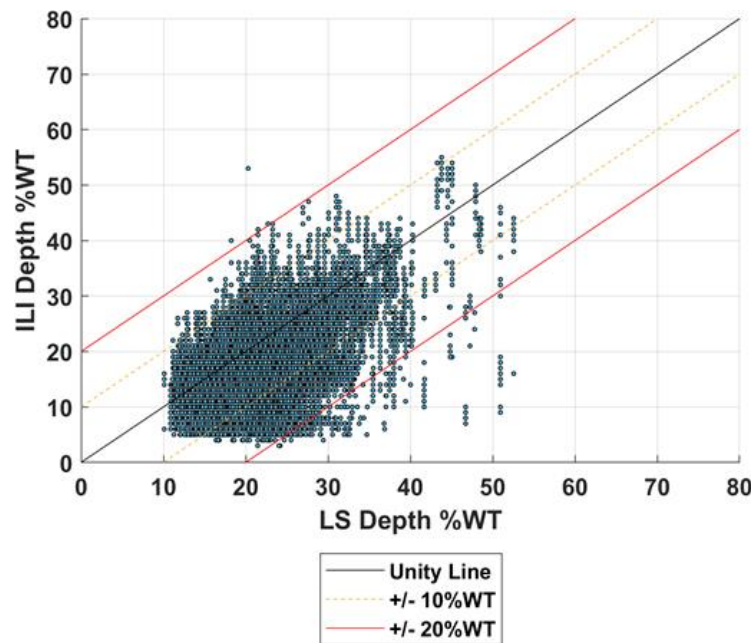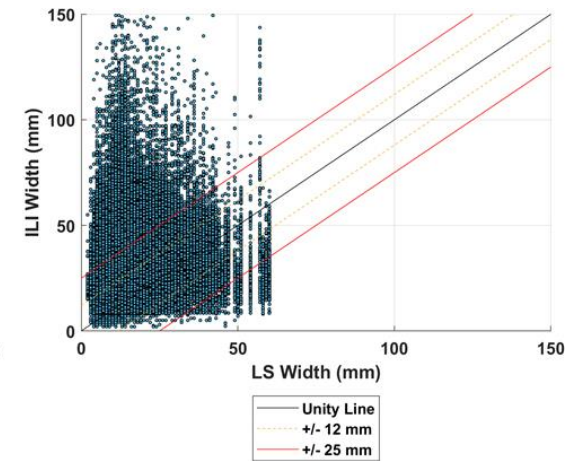
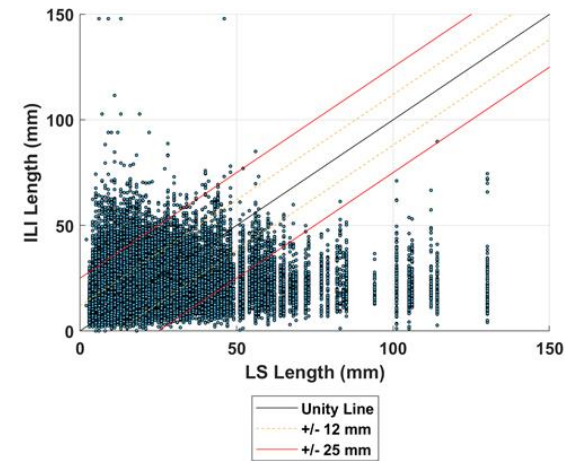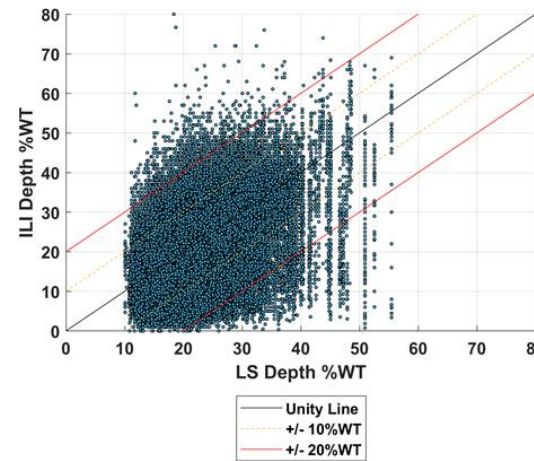# Trial Observations and Performance - Corrosion

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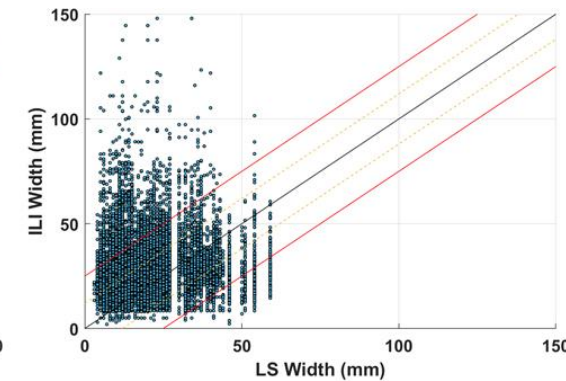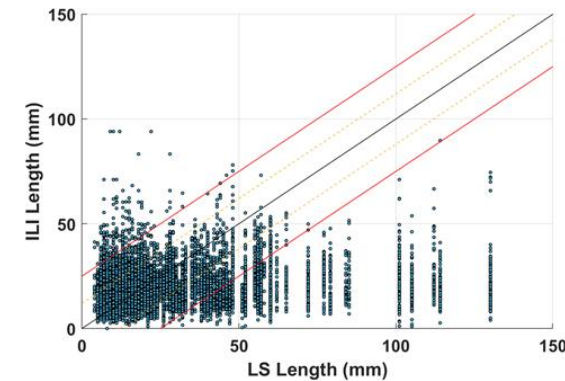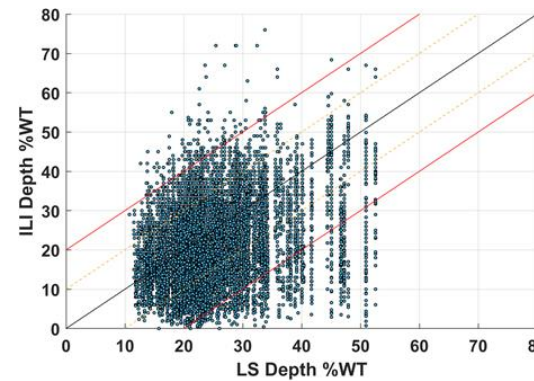 - Bias over estimate width of features
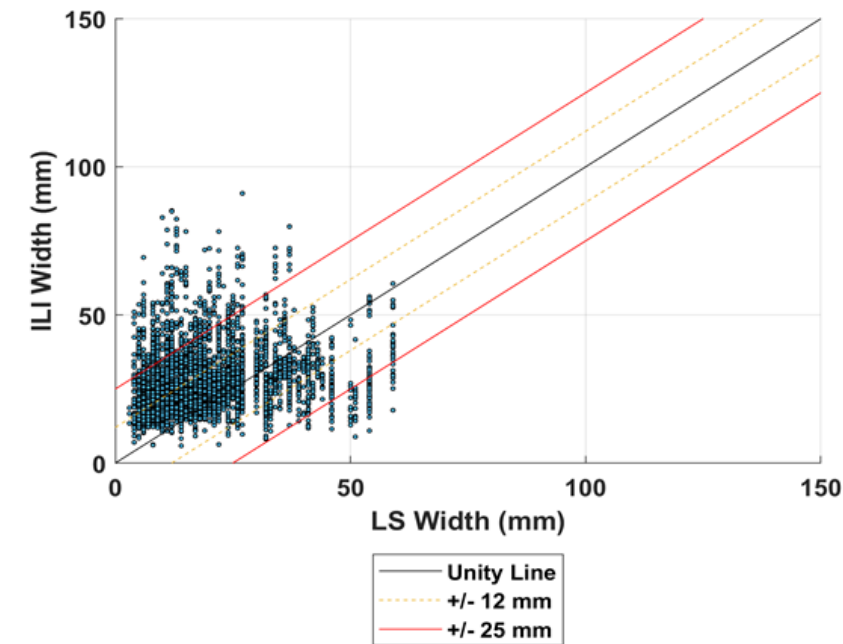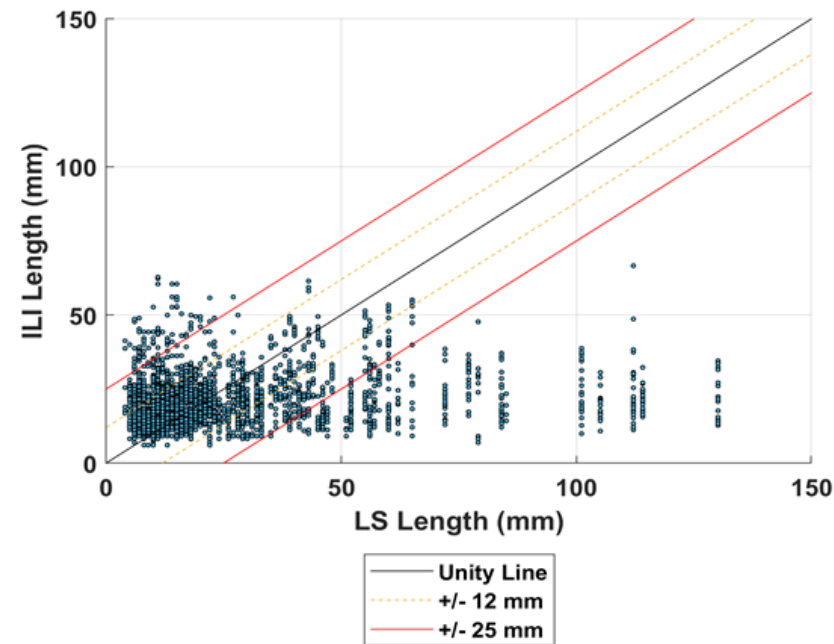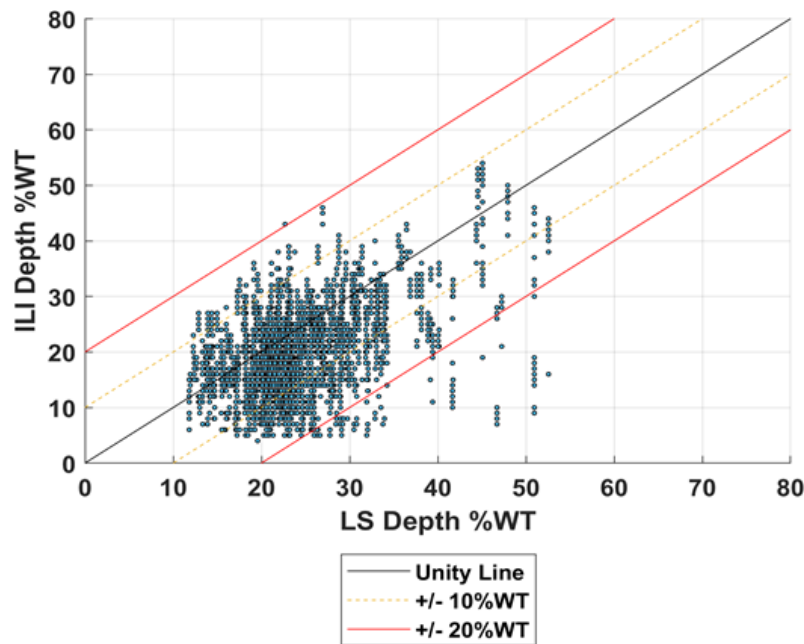
Trial Observations and Performance – Corrosion

- Similar performance observed for six magnetic ILI systems

- Ultrasonic tool provided the same performance
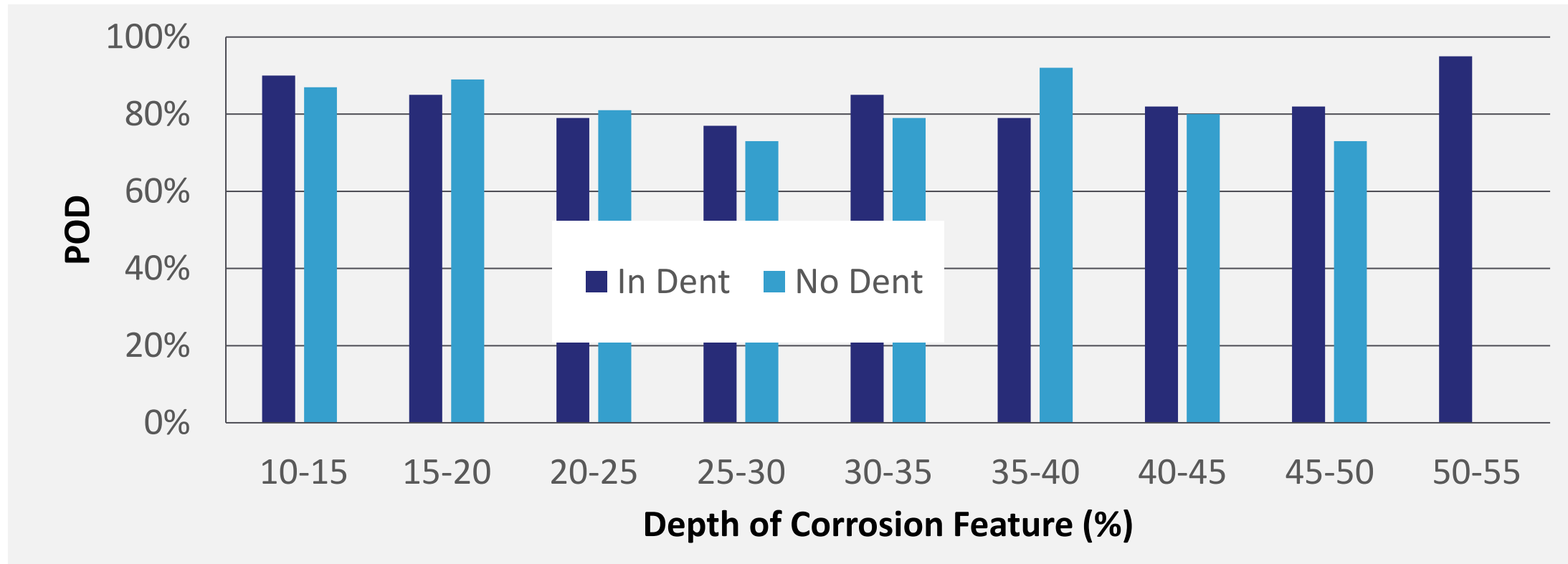
All Corrosion Features

All Corrosion Features on Dents

Trial Observations and Performance - Corrosion

- 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

Trial Observations and Performance - Corrosion

- Corrosion depth sizing, effect of dent coincidence for one ILI system
  - Small impact, if any, on average sizing variation
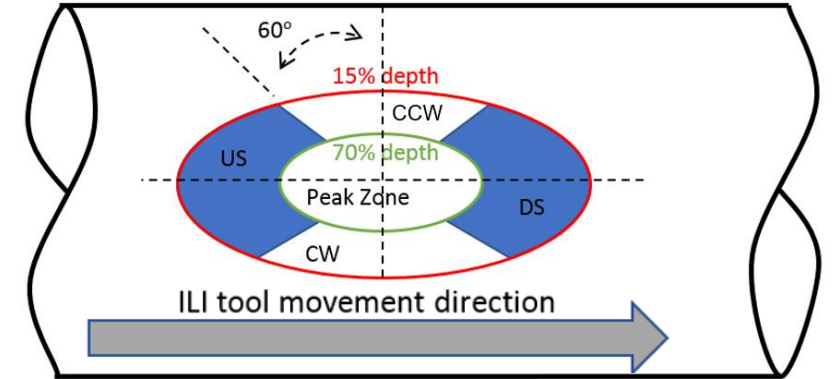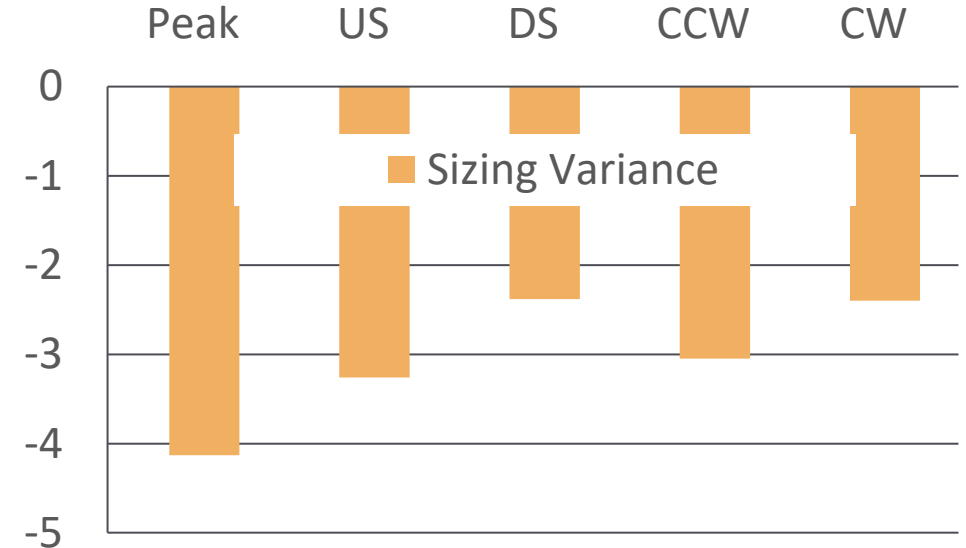 - In future, will consider as a function of dent depth
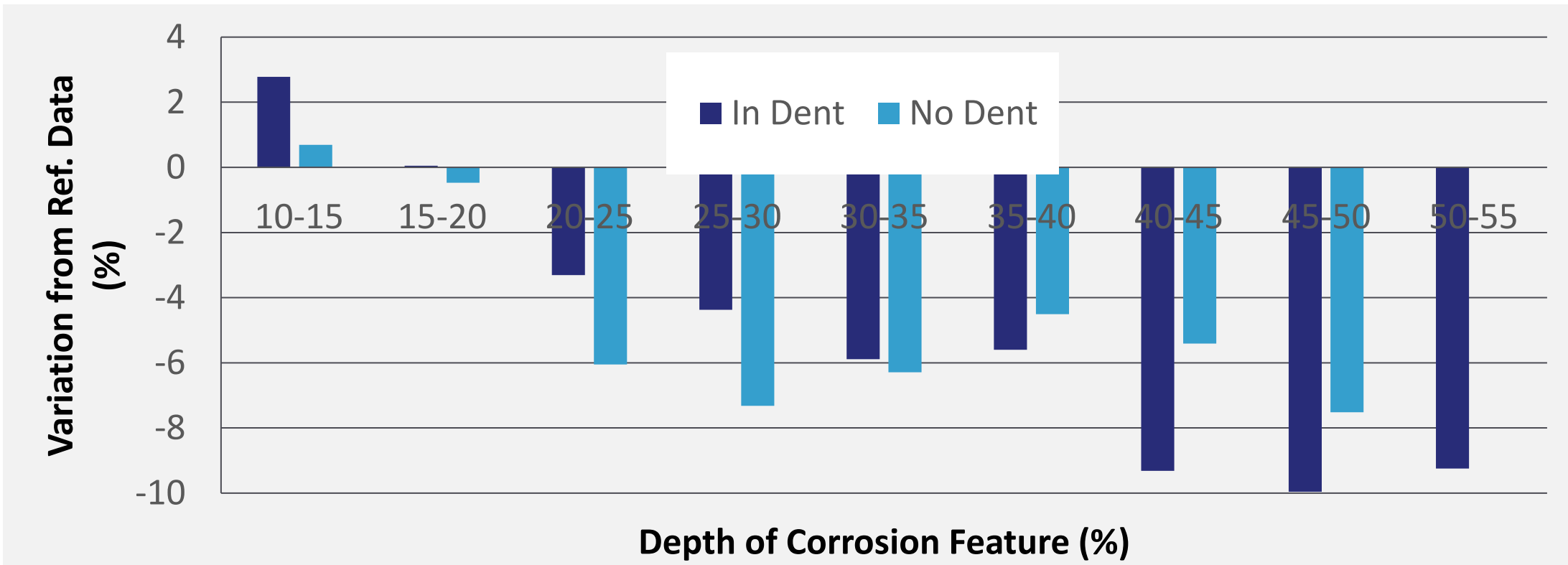
Trial Observations and Performance - Corrosion

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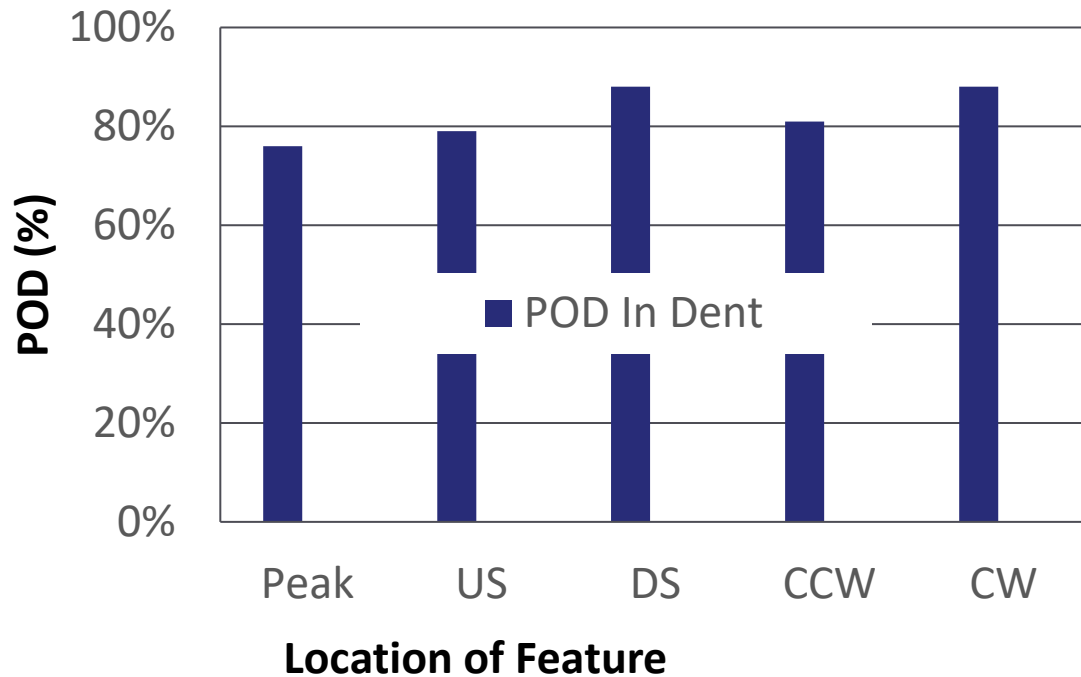
Trial Observations and Performance - Gouges

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- 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

Simulated
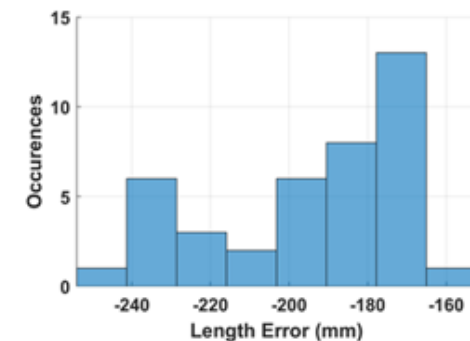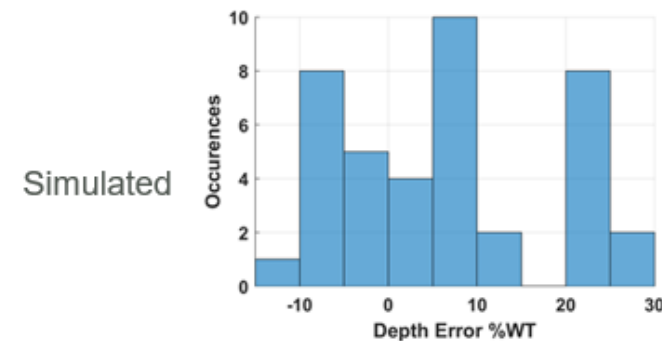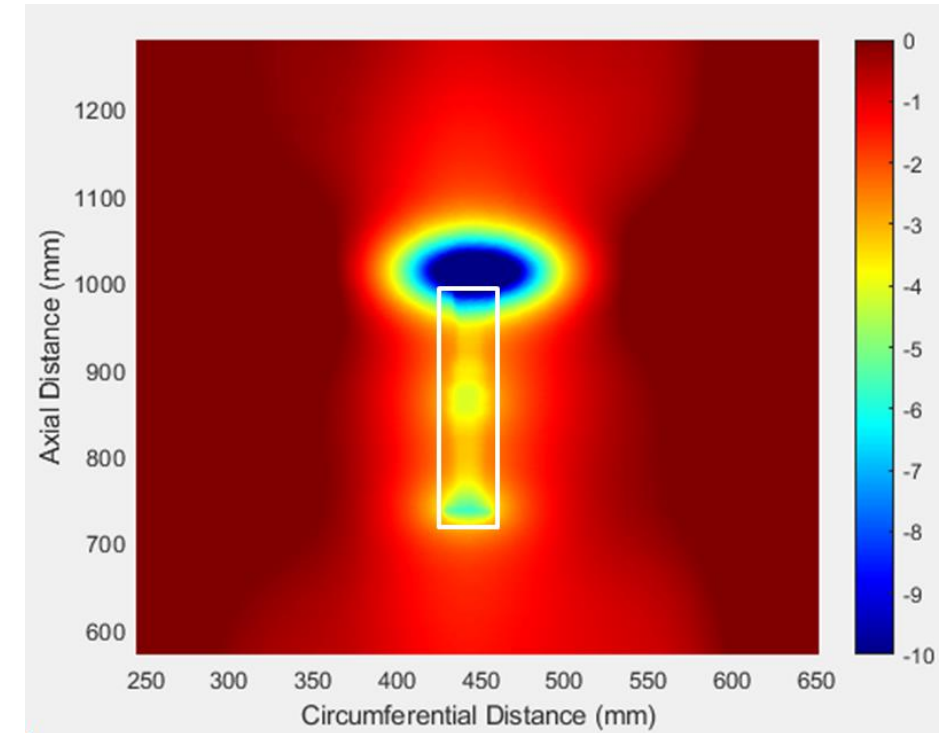
Trial Observations and Performance - Cracks

- ## 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

- Lengths
- Unity Line
- +/- 25 mm
- +/- 50 mm
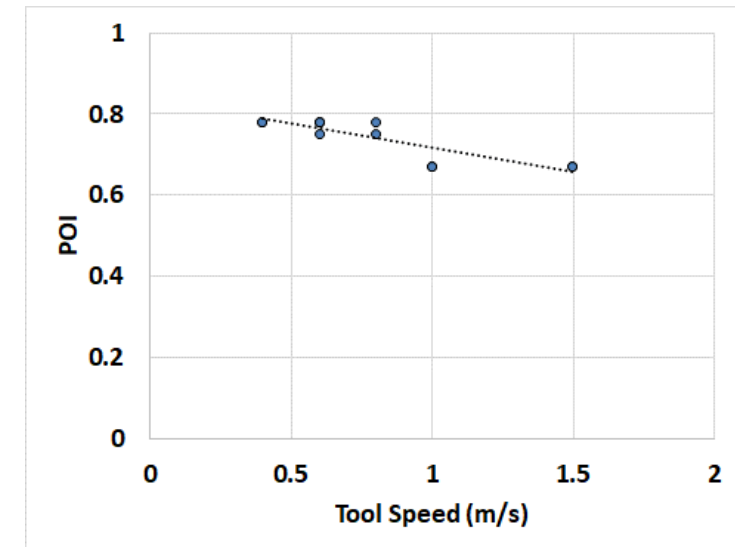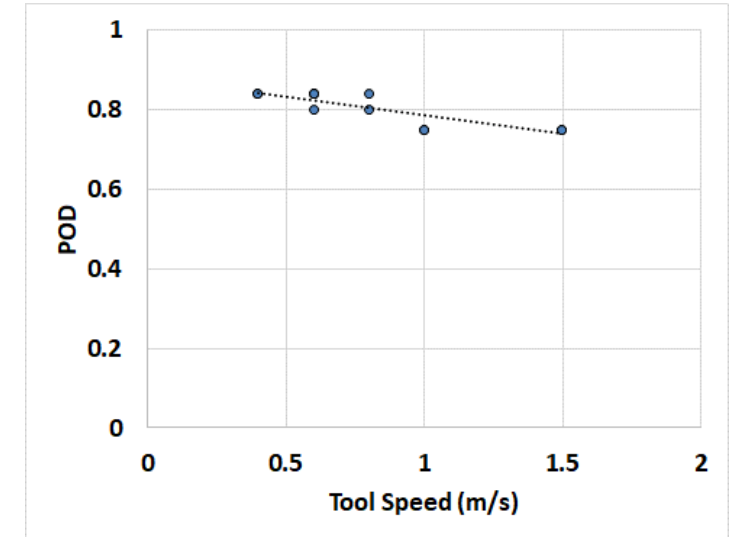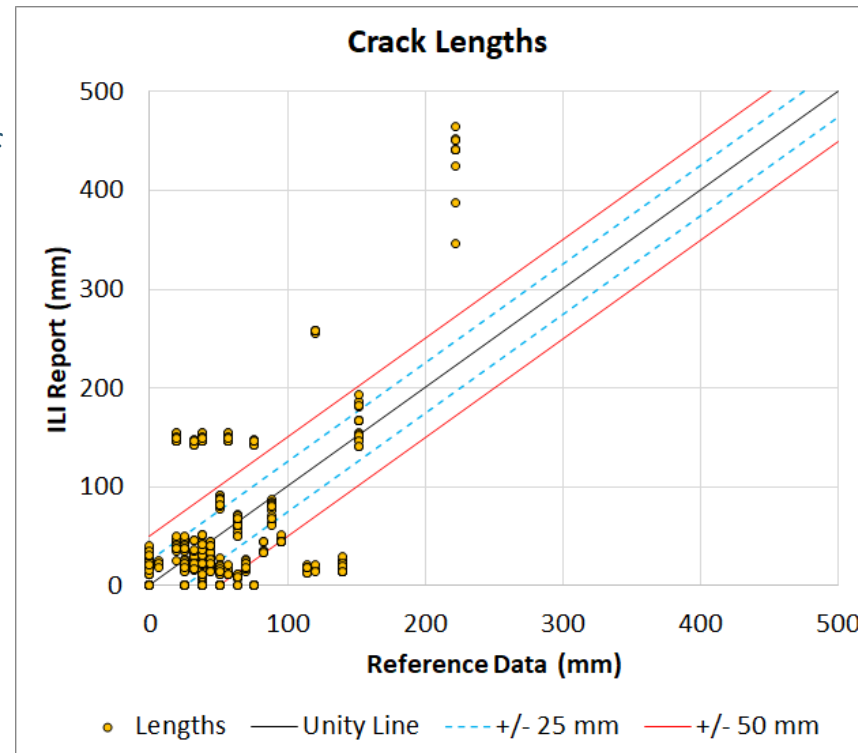
Next Steps

- 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.