Pipeline Research Council International, Inc.

PHMSA Presentation

Improving Assessment Methods for Dents & Cracks (Work Group 1)

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PHMSA Research & Development Meeting
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Mission Statement

To collaboratively deliver relevant and innovative applied research to continually improve the global energy pipeline systems.

PRCI Membership

- **32 Energy Pipeline Operating Companies**
  - 17 Natural Gas Transmission; 7 Liquid
  - 8 Liquid/Natural Gas
- **4 Pipeline Industry Organization (PIO) Members**
  - American Petroleum Institute (API)
  - Association of Oil Pipe Lines (AOPL)
  - Canadian Energy Pipeline Association (CEPA)
  - Operations Technology Development (OTD)
- **34 Associate Members & Technical Program Associate Members**
  - Australia, Canada, China, Europe, Japan, U.S.
- **Worldwide Research Organization**
  - 45 North American Companies (U.S. & Canada)
  - 25 Non-NA (Australia, Brazil, China, Europe, India & Japan)

Current Operator Membership

Natural Gas

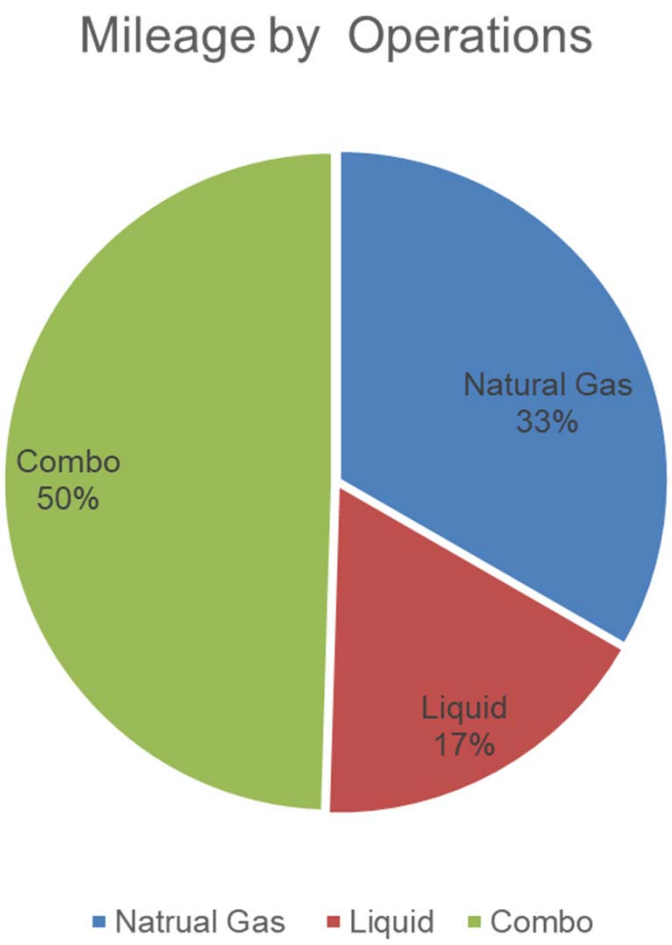
- Alliance
- ATCO
- Boardwalk
- Cadent
- Dominion
- Energy Transfer
- Gassco
- Gasunie
- GRTgaz
- National Fuel
- National Grid
- OTD
- PG&E
- SoCalGas
- Total
- TransGas
- Williams

Liquid

- API
- AOPL
- Buckeye
- Chevron
- Colonial
- ExxonMobil
- FHR
- Marathon
- Phillips 66
- Plains

Combo

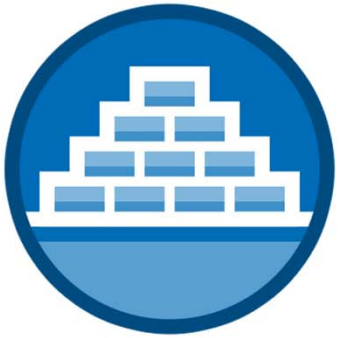
- ConocoPhillips
- Enbridge
- Enterprise
- Kinder Morgan
- Petrobras
- PetroChina
- Shell
- TransCanada



PRCI Research

PIPELINE TECHNICAL COMMITTEES

Corrosion



Design, Materials & Construction

Integrity & Inspection

Surveillance, Operations & Monitoring

PRCI Research

FACILITY TECHNICAL COMMITTEES

Compressor
& Pump Station

Measurement

Underground
Storage

Technology Development Center (TDC)

Presentation Overview

- Completed Project Knowledge
- Analyses in Progress
- Incremental Next Steps
- Example Projects
- Learning Collaboration
- Areas of Further Interest

Completed Project Knowledge

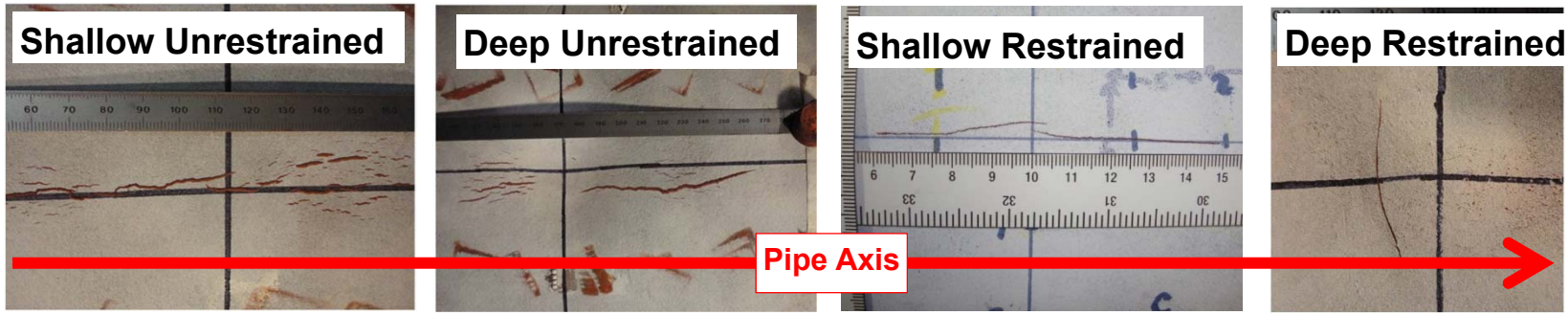
- **Mechanical Damage Testing (modern and vintage materials)**
  - Fatigue model validation data for:
    - *restrained & unrestrained dents*
    - *dents w/wo corrosion, weld & gouge interaction*
    - *a range of pipe sizes (D/t's), grades and vintages*
  - Burst model validation data for dents with gouges

  - Plain dents do not affect burst strength
  - Dent depth does not correlate with fatigue life, must consider shape
  - Fatigue testing of shallow restrained dents show different behaviour
  - Interacting corrosion or weld fatigue demonstrated to be manageable

Completed Project Knowledge

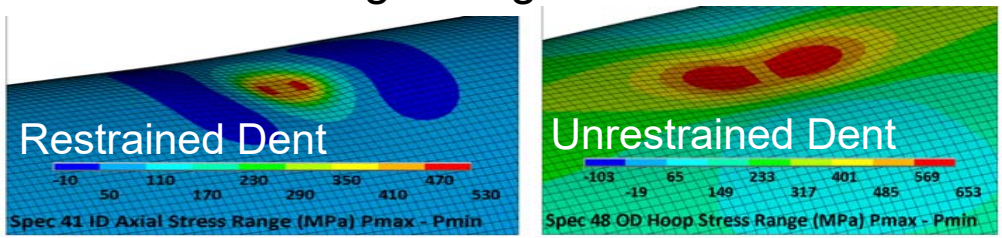
- **Dent Inspection & ERW Inspection**
  - Identified most likely dent fatigue cracking surface, orientation & location
  - Assembled NDE, pull-test & flow loop cracked dent & ERW samples
  - ILI and NDE trials considering cracked dents & ERW completed

- **Verifiable, Traceable, Complete Records**
  - ILI pipe property discrepancy identification
  - Grade & quality with portable hardness, strength & ductility (HSD) tester
  - Estimate yield, ultimate strength & toughness with in-ditch tools
  - Blind trials, validate non-destructive material characterization
  - Effects of hydro-testing on ERW seam anomalies defined



Analyses in Progress

- **Dent Fatigue Testing**
  - Real world (random shape) dents w/wo corrosion for model validation
  - Dent samples with cracks & interacting features for NDE & ILI testing
- **Dent Fatigue Life Assessment**
  - Validated FE based life assessment methodology for any dent
  - Can differentiate restrained & unrestrained dents using ILI data
  - Developed 3 tier single peak dent assessment methodology
  - Criterion to define dent / weld interaction
  - Weld & corrosion interaction life assessment
  - Unsusceptible features and operations can be identified
  - No effect of axial load on dent fatigue (until buckling)
  - Dent effect on buckling strength demonstrated



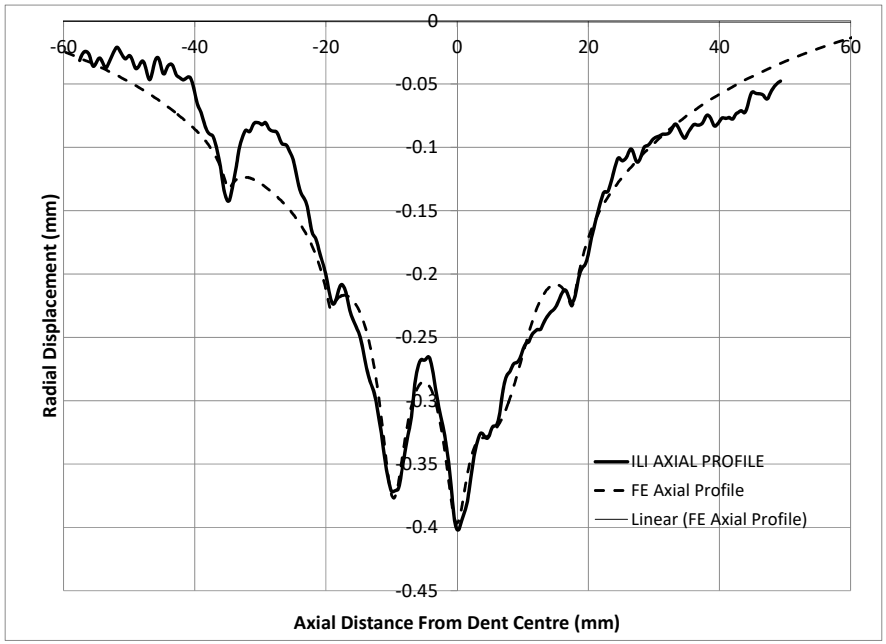
Analyses in Progress

- **Dent Remedial Action and Repair**
  - Excavation practice justification
  - State of practice guidance for dents
- **Dent Formation and Burst**
  - Dent formation strain estimated & related to cracking
  - Dent gouge burst estimated for high toughness material

Incremental Next Steps

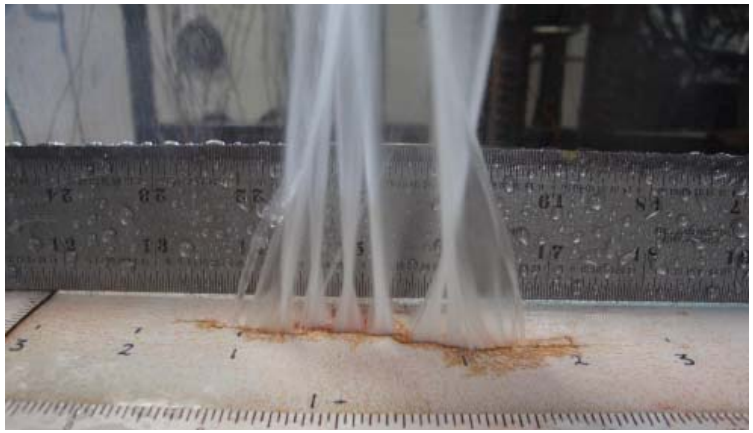
- **Mechanical Damage Testing & Inspection**
  - Fatigue in multi-peak dents to validate models
  - Fatigue of closely spaced dents to validate models
  - Create dent samples with a range of crack depths w/wo corrosion and weld interaction for NDE & ILI trials
  - Complete trials for NDE and ILI tools

- **Dent Fatigue Life Assessment**
  - Simple / engineering (Level 2 / screening) tools for multi-peak dents
  - Rules for dent interaction
  - Improved dent gouge fatigue life assessment
  - Consideration of conservatism of dent fatigue models



Incremental Next Steps

- **Dent Formation and Burst Testing**
  - Enhance burst assessment models to consider material toughness
  - Enhance dent formation strain estimation to predict cracking

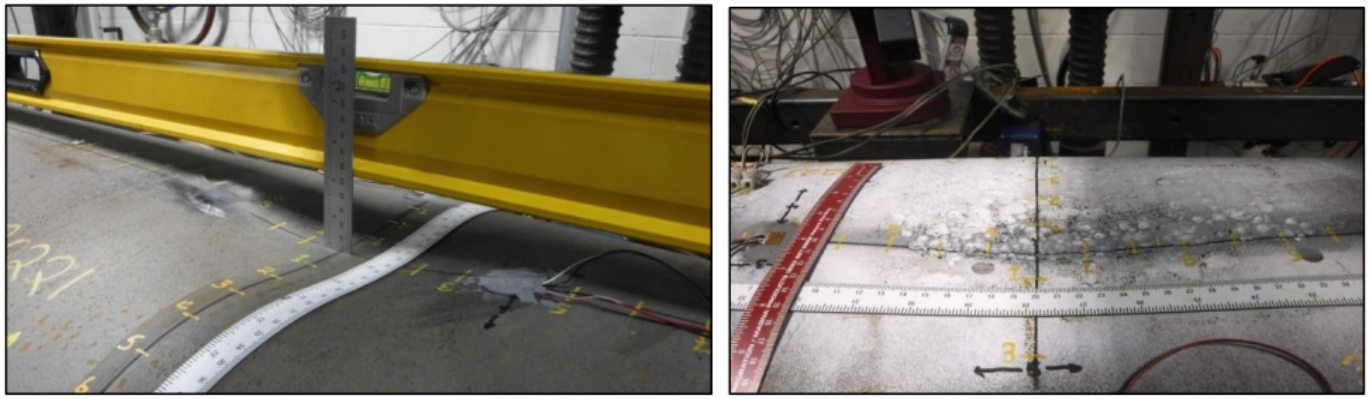


Example: Development of a PRCI ILI Performance Test Loop for Liquid Coupled Technologies

Creation of a flow loop designed for evaluating the performance of pipeline inspection technologies that operate in a liquid coupled environment.

Example: PHMSA Full Scale Testing of Interactive Features for Improved Models

This project addresses pipeline crack growth as influenced by complex operational circumstances by expanding on existing work performed through PHMSA and Pipeline Research Council International, Inc. (PRCI). Through full scale testing, the team will gather data on mechanical damage interacting with secondary features – gouges (with cracks and micro-cracks), corrosion, and welds. The team will create a database which will be used by others to validate and improve burst and fatigue strength models.

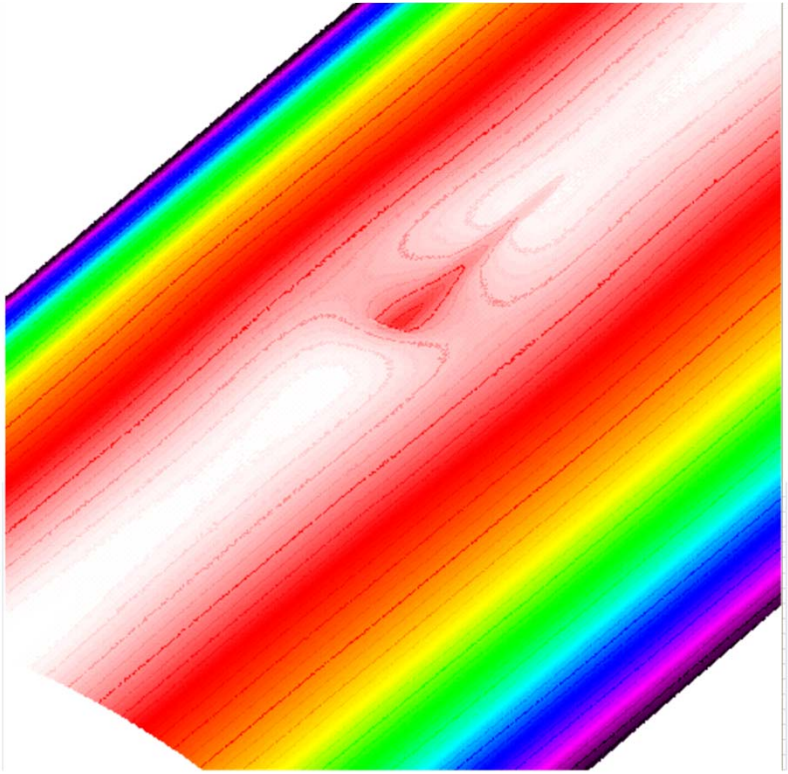


(a) (b)

Figure 13: Dent Shape with (a) 12 in Indenter (b) 24 in Indenter

Example: Quantifying Re-Rounding in Pipeline Damage Severity Models

This project focused on scoping the effects of re-rounding in the wake of a damage event. Several key conclusions were made based on validation by comparison to full-scale testing.



Learning Collaboration

Joint Dent Workshop RP 1183 (API/AOPL/PRCI), 8/9/2018

- History of the Stress Concentration Factor and Overview of the Dent Validation Collaborative Industry Program (DV-CIP) [ADVIntegrity]
- Failure at Plain Dents, Kinked Dents, & Gouged-Dents [BNLeis]
- Responding to ILI Indicated Dents with Metal Loss: GPAC Meeting Outcome and a Proposed Simplified Process [Kiefner]
- Dent Assessment with Considerations of Longitudinal Strain & Pipeline Vintage [CRES]
- API/PRCI Joint Workshop on Dent Assessment & Engineering Analysis Methods [BMT Fleet]
- Strain Based Dent Assessment [Blade Energy Partners]

Areas of Further Interest

- **Multiple areas of interest**
  - NDE for difficult to inspect lines (LSM, others)
  - Validated, industry-accepted fitness for service models
  - Standard terminology, definitions, and classifications for mechanical damage characterization (similar to POF)