Defect detection and characterization – PRCI activities

David Batte

Consultant to PRCI

DOT-reported incidents, 2002-2005

	Gas pipelines		Liquids pipelines	
	Incidents	**Fatalities**	**Incidents**	**Fatalities**
Operator excavation	**10**	**0**	**17**	**0**
Third party damage	**67**	**3**	**57**	**5**
All mechanical damage	**77**	**3**	**74**	**5**
Internal corrosion	**65**	**0**	**54**	**0**
External corrosion	**42**	**0**	**82**	**0**
SCC	**7**	**0**	**5**	**0**
All corrosion	**114**	**0**	**141**	**0**

Source: Smith, Mechanical Damage Workshop, March 2006

Not the whole picture: excludes non-penetrating defects!

PRCI aims – damage management

- **Providing operators with improved tools and procedures to address damage that threatens pipeline integrity**
- **Assessment**
  - Locate
  - Characterize and discriminate
  - Determine size and shape
  - Assess structural significance, severity
  - Determine safe, timely and proportionate response
- **Prevention, Mitigation**

Assessment of Integrity threats

	2007
In-service threats	
• External Corrosion	$800k
• Internal Corrosion	$200k
• SCC	$500k
• Mechanical Damage	$550k
Construction threats	
• Fabrication and construction defects	$850k

PRCI has developed Technology Roadmaps to address each of these threats and deliver improved management tools – based on members' needs and priorities

Corrosion – critical issues

Detect	**ILI reproducibility and accuracy; resolution, POD** **Identifying high-susceptibility IC locations**
Characterize	**General or local corrosion, MIC** **Secondary features; SCC**
Structural significance	**Site-dependent growth models** **Coherent suite of assessment methods**
Repair	**-**
Damage management	**Methodologies based on ILI, DA** **Re-inspection intervals optimization**

Corrosion – ongoing activities

- **External corrosion**
  - Accurate growth rate determination; measurement of growth from successive ILI runs, comparison of ILI tool performance
  - In-ditch tools; corrosion mapping, location and characterization in difficult-to-inspect areas
  - Improved structural significance assessment– influence of cyclic and biaxial loading, low toughness and high strength (part PHMSA co-funded)
  - Establishing re-inspection intervals using reliability-based methods
- **Internal corrosion**
  - Tools to identify corrosion-susceptible locations and measure wall loss
  - Development and demonstration of threat assessment guidelines

SCC – critical issues

Detect	**ILI reliability and accuracy, POD** **DA site selection**
Characterize	**Consistency of field diagnosis** **Depth, length measurement**
Structural significance	**Crack growth models** **Severity assessment, failure life**
Repair	**-**
Damage management	**Methodologies based on hydrotest, ILI, DA** **Re-inspection intervals**

SCC – Ongoing Activities

- **Site identification**
  - Guidelines for identifying SCC
  - SCC in areas of local deformation, dents
  - SCC in ethanol pipelines
- **Characterization**
  - ILI to detect identify and size SCC in gas and liquids lines
  - Field diagnosis and crack size measurement
  - External surface crack mapping
  - Capabilities of guided wave ultrasonics for axial cracks
- **Assessment**
  - SCC growth, dormancy, re-initiation and coalescence
  - SCC acceptance criteria
  - Guidelines for estimating re-assessment intervals after hydrotest, ILI, and DA

Mechanical damage – critical issues

Detect	**ILI capabilities; resolution, POD, current and next-generation tools.**
Characterize	**Damage dimensions and characterizing parameters. Plain dent discrimination**
Structural significance	**Screening models for ranking damage severity. Influence of secondary features** **Mechanics-based models for burst, delayed failure.** **Coherent suite of assessment methods**
Repair	**Pressure reductions for safe working** **Repair of less-severe damage (grinding)**
Damage management	**Methodologies for damage found by ILI, excavation** **Guidance, codes & regulations**

Mechanical damage – Ongoing activities

- **Detection and discrimination (part PHMSA co-funded)**
  - Evaluation of dual field and circumferential MFL, non-linear harmonics, UT
  - Differentiating the 3D magnetic signals from local deformation and stress
  - Performance characteristics of current ILI technologies
- **Assessment**
  - Ranking and screening of damage severity, life
  - Improved models for predicting burst, delayed failure
  - Mechanical damage at welds (PHMSA co-funded)
  - Behavior of dents with corrosion
  - Behavior of dent + gouge damage
  - Safe procedures for excavation and repair
- **Management**
  - Improved industry guidance

Weld defects – critical issues

Detect	**AUT accuracy; size and location, POD** **Difficult-to-inspect locations**
Characterize	**Benign or active defects?**
Structural significance	**Strain-based assessment methods**
Repair	**-**
Damage management	**Improved industry guidance for construction defect acceptance**

Weld defects – Ongoing activities

- **Assessment**
  - Factors affecting the properties of welds and HAZs
  - Fracture initiation criteria for high strength line pipe
  - Critical assessment of pipeline girth welds
  - Strain-based design: stress concentration at welds
  - Interaction of multiple defects under plastic collapse
  - Effects of constraint on fracture and plastic collapse
- **Management**
  - Criteria for evaluating failure susceptibility due to crack defects
  - Update on the evaluation of pipeline weld defects (API 1104)
  - Integration of multi-scale mechanics in weld integrity assessment (PHMSA co-funded)

Remaining gaps and priorities

- **Mechanical damage**
- **Corrosion**
- **Mechanical damage associated with corrosion, SCC, welds**
- **Stress Corrosion Cracking**

High priority needs – *a viewpoint*

- **Mechanical damage**
  - Better inspection technology, to discriminate the key features determining structural significance
  - Better assessment tools, especially to enable initial screening and severity ranking

How do we discriminate between plain dents and dents with corrosion, cracking?

What effect do small secondary features (corrosion, surface cracks) have on failure pressure, life, of gas and liquids lines?

Required outcome: Better regulations aligned with the improved inspection, discrimination and assessment capability, for safe, timely and proportionate responses when damage is discovered

High priority needs – *a viewpoint*

- **Corrosion**
  - Better understanding of pit growth rates in service

Measured and estimated rates from service vary between 1mil/year and 15mil/year (0.05-0.4 mm/y). MIC rates as high as 65 mil/year (1.6 mm/y) have been seen

Much laboratory data relates to free corrosion, not relevant to CP-protected pipe

Incubation times may vary widely. Correlations with soil type are uncertain. Dry summers reduce growth rates. Operating conditions change over the years. Each line/segment has its own growth rate.

Required outcomes: *Ability to focus on high-risk locations,*

Safe and timely re-inspection intervals

High priority needs – *a viewpoint*

- **Stress Corrosion Cracking**
  - Better understanding of crack growth rates in service

When does it start? Is the rate constant?

Measured and estimated rates from service have varied between 2mil/year and 60mil/year (0.05-1.5 mm/y).

Recent data from repeat hydrotests, ILI, suggest 10-15 mil/year (0.25-0.4 mm/y) may be a more relevant upper bound for many lines in service

Operating conditions change over the years. History is doubtful for older pipelines

Incubation times may vary widely. Correlations with soil type are uncertain. Each line/segment has its own growth rate.

Required outcomes: Ability to focus on high-risk locations,

Safe and timely re-inspection intervals

Thank you