ILI Requirements for Assessing Mechanically Damaged Pipelines

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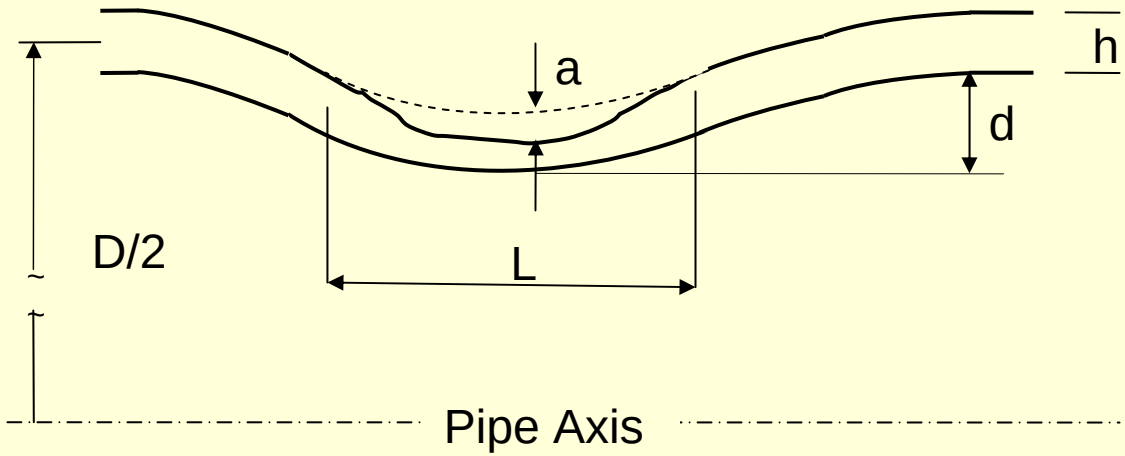
Inspection/ Repair/Leak Detection Session
Pipeline R&D Forum
March 22-24, 2005

Presentation Overview

- Failure Assessment Diagram for Mechanically Damaged Pipes
  - Establish critical parameters required for assessing structural integrity and developing an approach for prioritizing remedial action
- Review ILI Methods for Mechanical Damage
  - Capabilities and limitations
- Conclusions
- Recommended Future Research

Elements of Failure Assessment for Mechanically Damaged Pipes



Plastic Collapse:

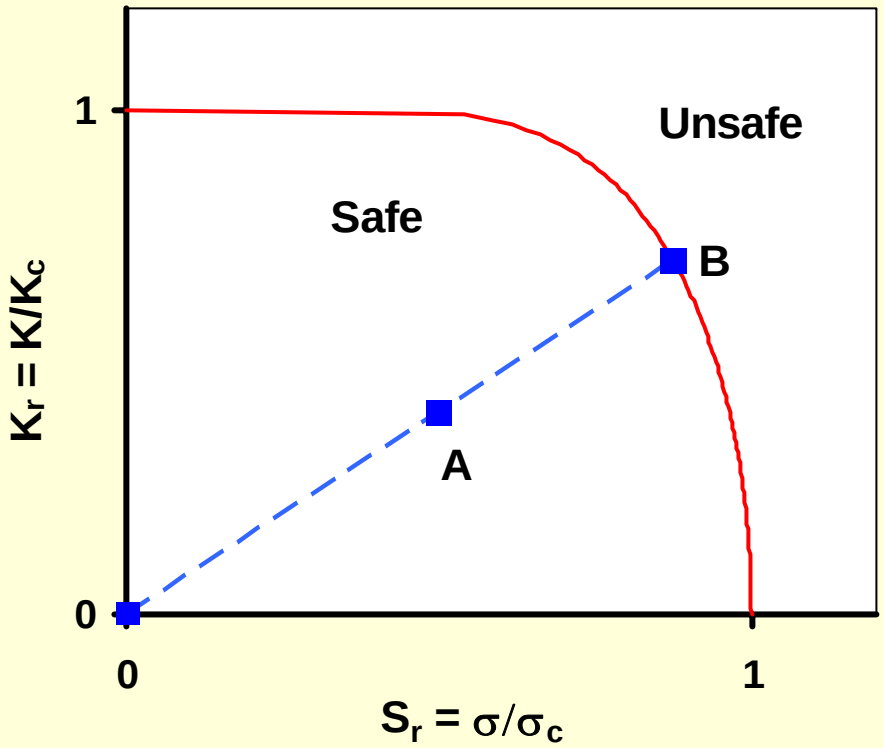
$$\sigma = \sigma_c; \qquad \sigma_c = \sigma_0\left(1 - a/h\right)F\left[\frac{L}{\sqrt{Da}}, \frac{d}{D,}, \frac{w}{L}, \frac{a}{h}, \ldots.\right]$$

Fracture:

$$K = K_c; \qquad K = \sigma\sqrt{\pi a}\,G\left[\frac{a}{h}, \sqrt{\frac{L}{Da}}, \frac{d}{D}, \ldots.\right]$$

Failure Assessment Diagram (FAD)

Elastic-Plastic Fracture Mechanics Provides the Connection Between These Extreme Failure Modes



State-of-the-Art Inspection for Mechanical Damage (MD)

- Emphasis has been on detection of damage
- Rudimentary sizing of damage
- Detailed methods for quantifying MD lacking
- Only qualitative or relative severity assessment of MD possible
  - Severity only qualitatively related to structural integrity of damaged pipe
- Primary inspection methods are High Resolution Deformation System, Magnetic Flux Leakage, Non Liner Harmonics, and Ultrasonics

High Resolution Deformation System

- Used to detect and measure dents
- Capable of measuring depth, length and width of dent
- Rank the dents based upon their geometric parameters
- Measurements are used in FEA to determine stress concentrations
- Pressure spectrum combined with fatigue analysis to estimate remaining life

Magnetic Flux Leakage (MFL)

- Builds on existing ILI technology for detecting corrosion
- Requires minimal modification for implementing technology
- Axial magnetization ideal for circumferential oriented damage, vice versa
- Residual stress, changes in microstructure, etc., modify magnetic properties and change MFL signal
- Trained analyst required to interpret decoupled MFL signal from which re-rounding and gouging can be detected
- Damage ranked qualitatively as being low, moderate-low, moderate, moderate-high or high

Non Linear Harmonics (NLH)

- A 10 KHz magnetic source is applied to the surface of the pipe which confines the magnetization to a surface layer
- The measured 30 KHz magnetic signal correlates with the surface strains
- Capable of detecting the residual surface strain from dent rerounding
- A gouge further enhances the residual surface strains and the measured signal
- Able to detect dents with gouges except for small inconsequential surface gouges
- A relative severity ranking of the dent/gouge is assigned, but is not a direct measure of the integrity of the pipe

Ultrasonic Detection

- Ultrasonics used to detect cracking in liquid pipelines where a coupling medium exists
- Typically an angle beam is used to detect a crack
- Resulting signal is sensitive to the incident beam angle and must be controlled which is difficult in the presence of a dent
- Shoulder of a gouge is a strong reflector that may mask the presence of a crack
- Lack of a coupling medium represents an obstacle for the application of ultrasonics to gas pipelines

Conclusions

- High Resolution Deformation pigs are capable of detecting and quantifying dents, but incapable of detecting metal loss or gouges/cracks in dents
- MFL and NLH are capable of detecting MD and establishing its width and length
- Neither method is capable of quantifying the depth of gouge, cracking, etc.
- Only qualitative or relative severity ranking of MD is possible
  - Severity is not a direct measure of structural integrity of pipe
    - impossible to relate severity ranking to a safety factor
- It is unlikely that Ultrasonics will be a viable tool for detecting and quantifying MD

Recommended Future Research

- ILI methods for detecting gouges containing cracks
- ILI methods for quantifying the depth of gouges/cracks
- More objective techniques for establishing the severity of mechanical damage
- Enhanced failure assessment methods for prioritizing MD