Are Smart Pigs Smart Enough?

Pipeline Safety Trust Conference

Geoff Foreman

November 2nd, 2017
In-line Inspection … did you know?

- Running at 9 mph
- Taking 1.2 Million measurements/second
- Examining the same surface area as 70 football pitches
- Analyzing 100,000 potential defects, on 20,000 screens of data
- Finding flaws the diameter of a quarter, or thinner than a matchstick, well before it can affect the safety of a pipeline
- ILI, the pipeline equivalent to Medical diagnostics
What is ILI and why do we use it?

- A means of inspecting a pipeline from end to end, all around the pipe.
- A robotic device (smart pig) that is pushed through the pipe by the product.
- It is non-intrusive and means energy can be delivered continuously without interruption during the inspection.
- Can identify flaws well before they become threats to the integrity of the pipeline.
- Running multiple ILI technologies, builds up confidence in identifying what and where potential threats are contained in a specific pipeline.
- When carried out on a regular basis, can determine the rate of defect growth, and thereby gives the means for assessments and repairs in a timely and planned manner.
- It is the most comprehensive means of screening for defects. (medical analogy – why do we have regular health screening tests?)
In-line Inspection ...is a process not a technology
Practicalities Of Pipeline Operations

Selection process of the ILI TOOL and VENDOR!

The Pipeline Characteristics
- Tool compatibility
- Product Type, Flow rate, Trap Length

The Defect Types
- Target features associated with a growth mechanism

The Required Accuracy
- PoD, PoI & sizing capability for the target cracks
ILI for Corrosion & Other Threats

Identify and size significant corrosion (volumetric metal loss)

NEAC & Grooving corrosion
Discriminate and identify more complex threats
Eg Mechanical Damage

Spatially map the pipeline centerline route (from the inside...)
Identify deformation threats

Magnetic Flux Leakage (“MFL”)

Piezoelectric Ultrasonic Wall Measurements

Transverse MFL

Geometry / Caliper Mapping
The right technology for every integrity challenge

Geometry (Dents and ovality)

Metal loss (corrosion & gouges)

CD tools (Cracks & LOF)

## Application Specifics

<table>
<thead>
<tr>
<th>Metal Loss Features</th>
<th>Crack Features</th>
<th>Deformation &amp; Geometry</th>
<th>Integrity Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>General corrosion</td>
<td>Hydrogen induced crack</td>
<td>Bending strain measurement</td>
<td>Corrosion growth assessment</td>
</tr>
<tr>
<td>Stress corrosion</td>
<td>Fatigue crack</td>
<td>Stress corrosion cracking</td>
<td>Electrochemical assessment</td>
</tr>
<tr>
<td>Pitting</td>
<td>Stress corrosion cracking</td>
<td>Fatigue crack</td>
<td>Electrochemical assessment</td>
</tr>
<tr>
<td>Micropitting</td>
<td>Stress corrosion cracking</td>
<td>Fatigue crack</td>
<td>Electrochemical assessment</td>
</tr>
<tr>
<td>Acid grooving</td>
<td>Stress corrosion cracking</td>
<td>Fatigue crack</td>
<td>Electrochemical assessment</td>
</tr>
<tr>
<td>Highly localized corrosion</td>
<td>Stress corrosion cracking</td>
<td>Fatigue crack</td>
<td>Electrochemical assessment</td>
</tr>
</tbody>
</table>
ILI Evolution – Metal loss & Cracking

Initial MFL ILI tools 1965
Mapping (IMU) pig 1986
1st Digital MFL HR tools 1998
POF Metal loss spec 1994
combo tools MFL + Caliper/IMU 2006
Introduction of Girth Weld spec 2016

- 1975 initial High Res MFL tools
- 1987 Pressure based reporting
- 1990 Computer disc (digital) reporting
- 1997 CMF (TFI) tool
- 2013 pin hole spec

Initial crack tool Elastic Wave 1982
Initial EMAT 2002
Absolute depth sizing 2010

- 1994 Initial USCD tool
- 2004 Initial USDuo. Phased Array tool
- 2017 HR CD tool
People and Training: ANSI/ASNT ILI-PQ-2005

- **Level 1**
  - Trainee
  - 6-12 months

- **Level 2**
  - Additional tasks and responsibility as level increases
  - Experience, Assessment, leadership
  - 18-24 months

- **Level 3**
  - 36-60 months

**Long Term Commitment to Certification**
- 6-12 months
- 18-24 months
- 36-60 months
Our technology enables us to detect over 20 different types of cracks. Please contact us for further information and to discuss your specific requirements.
UltraScan™ DUO
Crack Inspection Technology For Liquid Pipelines
Ultrasonic Crack Detection Evolution - Analysis and Reporting

Hardware

- 1st USCD Inspection
- EMAT Gen I
- DUO
- EMAT Gen 3
- CD P

Analysis

- Depth Estimation
- Crack profiling & SCC mapping
- Depth in %WT
- Absolute Depth based Reported
- Weld Misalignment
- New SCC Algorithm
- Absolute Depth based Reported

Reporting

- Reporting cycle 180-360 days
- Reporting cycle 110 days
- Tailored reporting CD 30-60 days
- Priority Scan EMAT 30 days

Notch Feature Sizing

Crack Abs Depth Incl. Tolerance

New analysis Attributes

Min detection Length 0.6”

Crack Abs Depth Incl. Tolerance

Tailored reporting CD 30-60 days

Priority Scan EMAT 30 days

1 Million Cracks Reported

CD Edge

Higher Resolution

Multiple Phased angle inspections

CD Double Circumferential Resolution = 3mm

EMAT Gen I

EMAT Gen 3

CD P

November 7, 2017
POD diagram - Percentage confidence increases with crack size.

What is the target crack size you need to detect? “x” times smaller than that which will fail!
Surface-breaking feature with the appearance of a LOF
Peak Depth 100% Length 0.5”
EmatScan™
Crack Inspection Technology for Gas Pipelines
**EmatScan CD – ERW Seam Weld**

<table>
<thead>
<tr>
<th>EMAT</th>
<th>Field</th>
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</thead>
<tbody>
<tr>
<td>Crack-Like</td>
<td>Feature Type</td>
</tr>
<tr>
<td>&gt; 0.2 inches</td>
<td>Surface Breaking Lack of Fusion</td>
</tr>
<tr>
<td>Depth</td>
<td>0.16 inches</td>
</tr>
</tbody>
</table>

**Dig Verification | lack of fusion in ERW**
Challenges for ILI – Potential failures post ILI
<table>
<thead>
<tr>
<th>Cause</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Debris in the pipeline can blind sensors</td>
<td>• Extensive cleaning - Data quality checks post run</td>
</tr>
<tr>
<td>• Using the wrong ILI tool for the threat</td>
<td>• ILI tool and Vendor capabilities – PRCI TDC testing</td>
</tr>
<tr>
<td>• Run the ILI too fast</td>
<td>• Post run Data quality check – Re-run</td>
</tr>
<tr>
<td>• No or poor Dig verification</td>
<td>• Make sure the ditch NDE is good – feedback!</td>
</tr>
<tr>
<td>• None Standard pipe</td>
<td>• Identify these areas and record their location</td>
</tr>
<tr>
<td>• Complex features</td>
<td>• Store the attributes in the database</td>
</tr>
<tr>
<td>• Not in the codes – No reporting std.</td>
<td>• Train analysts/algorithms to identify these</td>
</tr>
<tr>
<td></td>
<td>• Use alternative technologies not affected</td>
</tr>
<tr>
<td></td>
<td>• Overlay of different ILI runs data</td>
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<td></td>
<td>• Use combo tools ILI different defects in 1 run</td>
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<tr>
<td></td>
<td>• Derive unique analysis methodology</td>
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<tr>
<td></td>
<td>• Run experiments – burst test specimens</td>
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<tr>
<td></td>
<td>• Bring in 3\textsuperscript{rd} party expertise (i.e. PRCI)</td>
</tr>
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</table>
EmatScan CD – None Standard Seam Weld Inspection

Max. heights and misalignments of weld beads as stated in ISO 3183(2007) or API 5L(2004) as well as weld beads with widths up to 2 x wt are unproblematic. For pipeline seam welds not meeting these specifications, expert PII consultation is required regarding feasibility and performance.
Crack in dent
Detection and sizing using EmatScan CD tool & High Res Caliper.

2015 innovation in crack ILI
EmatScan CD – Seam Weld

Sound transmitted around the pipe

Conventional USCD Shear wave at 45 deg.
UltraScan Duo™ Crack Detection Phased Arrays

How do we make smart pigs smarter?
3D Visualization

Concept
• Provides 3D visual aid
• Advances beyond 2D BScan enabling accurate crack profiling
• Tool does the heavy geometric thinking
• Allows analyst to focus on accuracy & morphology

Automated Learnings

Concept
• Pattern Recognition with search tool
• Allows learning backwards
• Improved QC of inspection data
• Automated classification of new data

What we are currently developing
BAKER HUGHES
a GE company
Crack in Corrosion

Corrosion ;-  
Flat bottom vs steep pits?
Width – narrow vs wide?
Shallow or deep?

Need to know that the corrosion is present!
The shape of the corrosion can affect the amplitude of the returning sound at 45 deg?
Emat not affected as sound is travelling around the pipe therefore its reflector is not influenced.