Maximising Accuracy of MFL Pipeline Inspection

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Introduction

Pipeline Operator Challenges:

Role of Inline Inspection (ILI):

➢ Significant contribution to input data
➢ Contributing since the 1970s
➢ Reliable & Accurate data has a major impact in pipeline integrity management outcomes

➢ MFL technology is most run ILI service
➢ Vehicle / Hardware gets most focus
➢ Other factors play important role in providing reliable and accurate data:
  ✓ Software & feature recognition
  ✓ Data analysis: People & Process
  ✓ Algorithms & sizing models
  ✓ Performance validation, verification & improvement

ILI technology by runs
(Kimberlite report past 3 years)

Other* 39%
MFL 41%
UT 20%

* Other = Hi/low res Caliper, Eddy current, etc
Maximising accuracy of MFL pipeline inspection

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- 1. Accuracy
- 2. The inspection vehicle
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- Conclusions
MFL Accuracy

Detection or **POD**

*Will ‘it’ be seen?*

Identification or **POI**

*What is ‘it’?*

Sizing or **POS**

*What size is ‘it’?*
Accuracy

Detection or **POD**

*Will ‘it’ be seen?*

Identification or **POI**

*What is ‘it’?*

Sizing or **POS**

*What size is ‘it’?*
Accuracy evolution

1990s

- Detect pits from 50% wt
- Detect GML from 30% wt
- Depth sizing from +/-15%
- No width sizing accuracy
- Pre-POF defect types

mid 2000s

- Detect pits from 20% wt
- Detect GML from 10% wt
- Depth sizing from +/-10%
- Width sizing as std
- Valid for 4 POF defect types

Today (2019)

- Detect pits from 6% wt
- Detect GML from 4% wt
- Depth sizing from +/-8%
- Valid for 7 POF defect types
  + other anomalies...

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Impact of changing MFL accuracy

North America pipeline example:

Effect of improved accuracy on a single defect:

How this affects inspection results & outcome:

<table>
<thead>
<tr>
<th>Immediate Dig Criteria</th>
<th>HR Specification</th>
<th>SHR or SHR+ specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 70%</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>RPR ≤ 1.00</td>
<td>71</td>
<td>51</td>
</tr>
</tbody>
</table>

In this example:
- Caught additional potential health & safety risks
- 20 unnecessary digs removed. At $25k/dig, **saving = $0.5M**

Investing in ILI accuracy upfront leads at least 10x saving later
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Inspection Vehicle

MagneScan

Example: 6” MagneScan system delivering ‘Super High Resolution Plus (SHRP)’ service

VECTRA Gemini

Example: 24” VECTRA GEMINI system delivering ‘HD’ service

High density multiple ‘Triax’ sensor head

Optimised Magnetizer (ride, geometry, dynamics)

Synthesised interpretation to maximise insight and measures
MagneScan example

30 tracks recorded every 3.3mm

6” MagneScan – previous generation

72 tracks recorded every 2mm

6” MagneScan – latest generation (axial only)
MagneScan example

30 tracks recorded every 3.3mm
6” MagneScan – previous generation

72 tracks recorded every 2mm
6” MagneScan – latest generation (axial only)

Research Conducted:
➢ Pull testing data compared with extensive FEA models
➢ Wide range of defect types
➢ Optimal sensor density identified
➢ ‘Tightening the net’ further will not significantly improve sizing performance
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MFL Data

e.g. typical sample of external corrosion
MFL Data

Note: Grid for illustrative purposes only. Not representative of true scan-spacing dimensions

e.g. **100km pipeline**:
- +500 pixels high (# of sensors)
- 50 million pixels wide (# of scans)
- 100s GB of raw data
- Looking for defects as small as 5mm x 5mm
  (seeing even smaller 2mm x 2mm)
MFL Data

Note: Grid for illustrative purposes only. Not representative of true scan-spacing dimensions

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  (seeing even smaller 2mm x 2mm)

Software & Feature Recognition

Goals:
- Identify
- Classify
- Quantify
- Allow the Data Analyst to focus on most critical features and where manual expertise adds most value
### ‘Boxing’ Corrosion

<table>
<thead>
<tr>
<th>Detect</th>
<th>Identify</th>
<th>Classify</th>
</tr>
</thead>
</table>
| ➢ Typical area of external corrosion  
➢ Seam weld indication | ➢ Software ‘boxes’ every area it thinks is corrosion  
➢ Making an ‘internal / external’ call | ✓ Removing the seam weld boxes  
✓ Removing the ‘false’ metal loss boxes |
‘Big Data’ Supporting the evolution

Cloud Architecture

- Scalable, fast, secure
- Baker Hughes has 1PB of historic data
- 1 billion signals validated by analysts
- Metal Loss detection using **250,000,000** detected features

Continuous Improvement

- Managing sensitivity to pipeline variations
- Measuring and ensuring repeatability
- Updating & Improving performance over time

‘New Features’

- Being developed on challenging data set
- High volume of ‘black’ or poorly constructed welds
- Allowing focus on the ‘real’ pipeline threats

Girth Weld Anomalies
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Data Analysis: Process

- Typically 60 days from receipt of data (or up to 100 days for +150km)
- Every inch of pipe is visually assessed
- Software & feature recognition helping analysts focus on areas of importance
- Multiple QA/QC checkpoints
- **Right people / Robust Process**
**Data Analysis: People**

**Global ILI Analyst training**

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**Analysis Training & Certification Structure**

<table>
<thead>
<tr>
<th>Level</th>
<th>Experience (months)</th>
<th>Training (hrs)</th>
<th>Formal Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>6</td>
<td>80</td>
<td>Degree Qualified</td>
</tr>
<tr>
<td>Level II</td>
<td>18</td>
<td>160</td>
<td>Degree Qualified</td>
</tr>
<tr>
<td>Level III</td>
<td>36</td>
<td>500</td>
<td>Degree Qualified</td>
</tr>
</tbody>
</table>

*Experience months/Training hours. Technology dependent (see Written Practice – Global E-M003)*

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**Recruitment**
- Right ‘minds’ for the job
- SC/ENG Degree qualified

**Training**
- Long term investment
- Global standard
- On-job

**Ongoing Assessments**
- Re-certification every 2 years

**Long term career paths**
- Different technologies
- Additional skills
- SMEs

**Report Audits**
- Included in company KPIs
- Conducted regularly

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<-- Baker Hughes MFL qualification & certification requirements
Example: Report Audits

- Report audit program implemented across all ILI technologies
- Each analysis centre leads the yearly audit programme, governed by global technology lead
- Yearly target: 2% global MagneScan reports
- RCA conducted on all learnings
- Conducted on top of all other Quality reviews:
  - Concerns
  - QMS findings
  - Customer feedback
  - External Audits
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Sizing, or ‘POS’ process has 2 aspects:
- Characterise defect using several descriptors
- Predict the defect dimensions statistically using a sizing model

Relationship between recorded MFL and actual dimensions is complex and non-linear.

Impacted by a number of factors:
- Vehicle build
- Magnet strength
- Pipe wall thickness & material
- Vehicle speed
- Defect shape
22” MagneScan example

Sizing model data set consists of:
- Multiple pulls
- Wide speed range (0.2m/s – 7m/s)
- Multiple defect types

Resulting in over 10,000 defects

Example pull through results (22” MagneScan)

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Performance vs 90%</th>
<th>Specification level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Slots</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>Axial Grooves</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>General ML</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>Pitting</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>Pinhole</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>Circ. Grooves</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td>Circ. Slots</td>
<td>exceeded</td>
<td>SHR/SHRP</td>
</tr>
<tr>
<td><strong>All</strong></td>
<td><strong>Exceeded – 92%</strong></td>
<td><strong>SHR/SHRP</strong></td>
</tr>
</tbody>
</table>
Case Study: Bespoke sizing models

Customer Challenge:
- Early onset of internal corrosion
- Very high volume of specific pit & pinhole type defects

Solution
- Sizing model built to target:
  - specific defect types
  - Specific depth ranges

Defect Spools
- Defect machining to fit corrosion profile
- Increased population of low-level pitting defects
- External Mill overlapping with internal pits
- Overlapping pitting defects

Results
- POD 100% >5%
- POS +/-5% @ 97% confidence
- Validated performance using UT probes
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Validation

Recap: 6” Latest Generation MagneScan

✓ Overall performance exceeding the target specification

Customer challenge

Specific defect spools where ‘blind testing’ was carried out

100% detection of features above published specification

Repeatable results on defects below specification (e.g. 2x2mm)
Verification

MagneScan ILI data vs Dig data

Extensive Verification:

- **Thousands** of data points
- Range of diameters from 6–36”
- Ranging across **all 7 POF** defect types
- Feedback provided by operators from Asia, Europe & North America

➢ Consistently beating published POS (+90%)
Verification → Improvement

MagneScan ILI data vs Dig data

Super High Resolution ‘Plus’

Specifications for pinholes & Grooves introduced
Continuous Improvement

- ‘DigCom’ Software introduced
- Getting more benefit from increased use of laser scanners
- Enabling match of pits & pinholes in areas of complex corrosion

‘Truth Data’
→ driving change & optimising performance

- Extensive performance database
- Over 60,000 MagneScan defects
- Regular customer performance reviews
- Outlier reduction & elimination
- Enhanced training & processes
- Additional & improved specifications
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Conclusions
Conclusions

Reliable & accurate data ... not just an MFL tool ... It’s a system

... More to come from the data being gathered today
Thank You ...