ASSESSING MECHANICAL DAMAGE USING MULTIPLE DATA SETS IN ILI

Abel Lopes
Market Development Manager EH
14th November 2012

www.tdwilliamson.com
Failure Causes

Source: 8th Report of the European Gas Pipeline Incident Data Group
Failure Causes

Figure 18  Distribution of major spillage causes

Source: Performance of European cross-country oil pipelines
Statistical summary of reported spillages in 2010 and since 1971

Prepared by the CONCAWE Oil Pipelines Management Group’s Special Task Force on oil pipeline spillages (OP/STF-1)
## Technology Limitations

### Table 1: Types of ILI Tools and Inspection Purposes

<table>
<thead>
<tr>
<th>Anomaly</th>
<th>Imperfection/Defect/Feature</th>
<th>Metal Loss Tools</th>
<th>Crack Detection Tools</th>
<th>Deformation Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Magnetic Flux Leakage (MFL)</td>
<td>Ultrasound Compression Wave</td>
<td>Ultrasound Shear Wave</td>
</tr>
<tr>
<td>Metal Loss</td>
<td>Standard Resolution (SR)</td>
<td>High Resolution (HR)</td>
<td>Detection (A) Sizing (B)</td>
<td>Detection (A) Sizing (B)</td>
</tr>
<tr>
<td>External Corrosion</td>
<td>Detection (A) Sizing (B)</td>
<td>Detection (A) Sizing (B)</td>
<td>No Detection</td>
<td>No Detection</td>
</tr>
<tr>
<td>Internal Corrosion</td>
<td>No ID/outer diameter (OD) discrimination</td>
<td>No Detection Sizing (B)</td>
<td>No Detection Sizing (B)</td>
<td>No Detection Sizing (B)</td>
</tr>
<tr>
<td>Gouging</td>
<td>No Detection</td>
<td>No Detection</td>
<td>No Detection Sizing (B)</td>
<td>No Detection Sizing (B)</td>
</tr>
<tr>
<td>Crack-Like Anomalies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow Axial External Corrosion</td>
<td>Detection (A) Sizing (B)</td>
<td>Detection (A) Sizing (B)</td>
<td>Detection (A) Sizing (B)</td>
<td>Detection (A) Sizing (B)</td>
</tr>
<tr>
<td>Stress Corrosion Cracking</td>
<td>No Detection</td>
<td>No Detection</td>
<td>No Detection Sizing (B)</td>
<td>Limited Detection Sizing (B)</td>
</tr>
<tr>
<td>Fatigue Cracks</td>
<td>No Detection</td>
<td>No Detection</td>
<td>No Detection Sizing (B)</td>
<td>Limited Detection Sizing (B)</td>
</tr>
<tr>
<td>Long Seam Cracks, etc.</td>
<td>No Detection</td>
<td>No Detection</td>
<td>No Detection Sizing (B)</td>
<td>No Detection Sizing (B)</td>
</tr>
<tr>
<td>Circumferential Cracks</td>
<td>No Detection</td>
<td>Detection (C) Sizing (G)</td>
<td>No Detection Sizing (B)</td>
<td>No Detection Sizing (B)</td>
</tr>
<tr>
<td>Hydrogen-Induced Cracking (HIC)</td>
<td>No Detection</td>
<td>No Detection</td>
<td>Detection (A) Sizing (B)</td>
<td>Limited Detection</td>
</tr>
<tr>
<td>Deformation</td>
<td>Sharp Dents</td>
<td>Detection (E) Sizing (F)</td>
<td>Detection (E) Sizing (F)</td>
<td>Detection (E) Sizing (F)</td>
</tr>
</tbody>
</table>

(A) For additional information, refer to API 1163.³

---

For detailed information on the types of ILI tools and their limitations, refer to the API 1163 standard. This table provides a comprehensive overview of the tools and their applications in detecting various types of anomalies within pipelines.
TDW Offer

SPIRALL/MDS
Value of Multiple Datasets

**Value of Multiple Datasets**

- **MFL w/IDOD**
  - Volumetric Anomalies
  - Mill Anomalies
  - Extra Metal
  - Internal/External Classification
  - Dents

- **SMFL**
  - Gouging
  - Narrow Axial Corrosion
  - Selective Seam Corrosion
  - Planar / Crack-like Seam Anomalies
  - Volumetric Anomalies (pipe body or seam)
  - Mill Anomalies

- **DEF**
  - Ovalities
  - Dents
  - Misalignments
  - Other bore changes

- **Residual / Low Field Magnetization**
  - Permeability Anomalies – Hard spots
  - Mechanical Stress
  - Pipe Characteristic Changes

- **Planar versus Volumetric Axially oriented Anomalies**
  - Metal Loss in Seamless Pipe
  - Metal Loss crossing Girth Welds

- **Dents with Metal Loss**
  - Pipe Characteristic Changes
  - Gouging/ML without dent

- **Dent with residual stress**

- **Dent with Volumetric Metal Loss**

- **Pipeline Performance**

- **Pipeline Performance**

- **Pipeline Performance**

- **Pipeline Performance**
Axial MFL
Axial MFL

- Normalized Defect Length, L/A
- Normalized Defect Width, W/A
- Axial Slotting
- Axial Grooving
- Pitting
- General
- Pinhole
- Circumferential Slotting
- Circumferential Grooving
- Axial MFL

Diagram showing the classification of defects with normalized parameters.
SpirALL™ MFL Technology

Normalized Defect Length, L/A
Normalized Defect Width, W/A
Axial Slotting
Axial Grooving
Pitting
General
Pinhole
Circumferential Slotting
Circumferential Grooving

SpirALL™ MFL
SpirALL™ MFL Technology

- Magnetizer
  - SMFL concept enables Multiple DataSet platform
Axial MFL + SMFL
Axial MFL + SMFL

Overlap = Enhanced Characterization
Axial MFL + SMFL

- 16-inch inspection tool runs indicated that SpirALL™ MFL technology successfully identifies narrow axial defects that normally would not be reported by axial MFL alone.
Axial MFL + SMFL

- By combining axial MFL with SpirALL™ MFL in the same run, it becomes possible to identify the anomaly as a metal loss feature that happens to be in the seam weld instead of a crack-like feature in the seam.
The Multiple DataSet Advantage
Single Dataset – MFL

- Detection
- Identification
- Determination and Sizing
Characterization

Metal Loss crossing and within a girth weld
Characterization

- Mechanical Damage
Characterization

- Axial (Planar) Defects
Characterization

- Seam Weld Defects
Characterization

Planar / Crack-like Anomalies

MFL

SMFL

Long Seam

Seam Anomalies

1  2  3
Characterization

Planar / Crack-like Anomalies

Anomaly 1, 2 and 3 (left to right): zoomed in SMFL screenshot with dig photo

<table>
<thead>
<tr>
<th>#</th>
<th>Descr.</th>
<th>ILI %</th>
<th>Field %</th>
<th>ILI Length (mm)</th>
<th>Field Length (mm)</th>
<th>ILI Width (mm)</th>
<th>Field Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planar</td>
<td>19</td>
<td>16</td>
<td>109</td>
<td>140</td>
<td>1.3</td>
<td>Linear</td>
</tr>
<tr>
<td>2</td>
<td>Planar</td>
<td>29</td>
<td>14</td>
<td>61</td>
<td>73</td>
<td>1.8</td>
<td>Linear</td>
</tr>
<tr>
<td>3</td>
<td>Planar</td>
<td>15</td>
<td>16</td>
<td>188</td>
<td>198</td>
<td>2.0</td>
<td>Linear</td>
</tr>
</tbody>
</table>
Residual and Low Field MFL
Two different steel lattices will produce two different residual measurements (1,2)

This happens with hard spots, heat affected zones, and stress.
Steel Microstructure
Steel Microstructure

- Low Carbon
Steel Microstructure (High-carbon)

- High Carbon
Hard Spot / Crack

Figure 11. Photomicrograph of cracking initiating in a hard spot.
Mechanical Damage
Re-rounded versus Cycled Dents

T_{zero}: Pipeline becomes loaded
Re-rounded versus Cycled Dents

Re-rounded dent signature

Cycled dent signature, notice the strong "halo" effect
ASME B31.8 provides non-mandatory Appendix R which outlines methods for estimating strains in a dent:

- Enhancements to the ASME formulas, suggested by recent industry research, have been incorporated.
- Computations can be carried out using high resolution deformation data.
- Local dent strain can be estimated by analyzing the deformed shape.
- The Battelle prioritization model is then supplemented:
  - If a dent exhibits strain > 6% then considered higher priority.
• Mechanical Damage
• Utilization of Battelle Mechanical Damage Prioritization Model developed in 2002
  • PRCI L52084
  • Supplemented with:
    • Dent Strain
    • SMFL for gouging and metal loss
    • Proximity to girth and seam weld

Prioritization

High Magnetization Data

Low Magnetization Data

Apply Decoupling

Decoupled Signal?

No

No

No

Yes

Yes

Yes

No

No

No

Yes

Yes

Y...
<table>
<thead>
<tr>
<th>Doc Start</th>
<th>Dent Depth (in)</th>
<th>Orientation (Deg)</th>
<th>Description</th>
<th>Seam or not</th>
<th>Depth %</th>
<th>Dent Length (in)</th>
<th>Severity Number</th>
<th>Final Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>563805.8569</td>
<td>0.32</td>
<td>146</td>
<td>Dent w/ Metal Loss - Re-rounded (3.63% Strain)</td>
<td>2.0%</td>
<td>4.24</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>659396.4219</td>
<td>0.19</td>
<td>6</td>
<td>Dent w/ Metal Loss (3.03% Strain)</td>
<td>1.2%</td>
<td>2.24</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>280132.3133</td>
<td>0.17</td>
<td>301</td>
<td>Dent w/ Metal Loss - Re-rounded (3.73% Strain)</td>
<td>1.1%</td>
<td>2.36</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>377931.8188</td>
<td>0.16</td>
<td>299</td>
<td>Dent w/ Metal Loss - Re-rounded, Found in SprA1L (4.75% Strain)</td>
<td>1.0%</td>
<td>4.24</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>567775.0268</td>
<td>0.16</td>
<td>334</td>
<td>Dent w/ Metal Loss - Re-rounded (2.27% Strain)</td>
<td>1.0%</td>
<td>3.18</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>366167.334</td>
<td>0.15</td>
<td>194</td>
<td>Dent w/ Metal Loss, Found in SprA1L (1.47% Strain) Cycled</td>
<td>0.9%</td>
<td>3.0</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>679479.7892</td>
<td>0.14</td>
<td>352</td>
<td>Dent w/ Metal Loss - Re-rounded (1.67% Strain)</td>
<td>0.9%</td>
<td>11.43</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>276699.0574</td>
<td>0.16</td>
<td>65</td>
<td>Dent w/ Metal Loss - Re-rounded (2.67% Strain)</td>
<td>0.9%</td>
<td>1.53</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>274771.2529</td>
<td>0.12</td>
<td>103</td>
<td>Dent w/ Metal Loss - Re-rounded, Found in SprA1L</td>
<td>0.8%</td>
<td>3.06</td>
<td>1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>281118.0863</td>
<td>0.47</td>
<td>173</td>
<td>Re-rounded (8.7% Strain)</td>
<td>2.9%</td>
<td>4.95</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>154897.5576</td>
<td>0.38</td>
<td>150</td>
<td>Re-rounded (8.56% Strain)</td>
<td>2.4%</td>
<td>5.42</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>82737.5068</td>
<td>0.24</td>
<td>352</td>
<td>Cycled</td>
<td>1.5%</td>
<td>4.71</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>608442.364</td>
<td>0.15</td>
<td>23</td>
<td>Re-rounded</td>
<td>0.9%</td>
<td>1.06</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>317119.5066</td>
<td>0.15</td>
<td>327</td>
<td>Re-rounded</td>
<td>0.9%</td>
<td>2.00</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>398412.3769</td>
<td>0.15</td>
<td>194</td>
<td>Dent w/ Metal Loss, Found in SprA1L (1.88% Strain)</td>
<td>0.9%</td>
<td>4.83</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>202455.0887</td>
<td>0.13</td>
<td>3</td>
<td>Re-rounded</td>
<td>0.8%</td>
<td>1.65</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>275951.9093</td>
<td>0.13</td>
<td>266</td>
<td>Cycled</td>
<td>0.8%</td>
<td>1.53</td>
<td>2</td>
<td>Moderate High</td>
<td></td>
</tr>
<tr>
<td>619295.5526</td>
<td>0.4</td>
<td>150</td>
<td>Re-rounded (4.58% Strain)</td>
<td>2.5%</td>
<td>5.42</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>364414.8644</td>
<td>0.39</td>
<td>162</td>
<td>Re-rounded (5.37% Strain)</td>
<td>2.4%</td>
<td>4.71</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>399695.4012</td>
<td>0.39</td>
<td>154</td>
<td>Re-rounded (4.7% Strain)</td>
<td>2.4%</td>
<td>6.39</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>605422.7802</td>
<td>0.37</td>
<td>144</td>
<td>Re-rounded (1.03% Strain)</td>
<td>2.3%</td>
<td>4.95</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>287602.8391</td>
<td>0.35</td>
<td>163</td>
<td>Re-rounded (4.5% Strain)</td>
<td>2.2%</td>
<td>3.65</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>654664.5542</td>
<td>0.35</td>
<td>141</td>
<td>(2% Strain)</td>
<td>2.2%</td>
<td>4.48</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>632760.8801</td>
<td>0.32</td>
<td>130</td>
<td>Cycled (2.3% Strain)</td>
<td>2.0%</td>
<td>3.65</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>475118.7453</td>
<td>0.23</td>
<td>356</td>
<td>Re-rounded (5% Strain)</td>
<td>1.4%</td>
<td>2.12</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>62031.35495</td>
<td>0.23</td>
<td>281</td>
<td>Re-rounded (2.65% Strain)</td>
<td>1.4%</td>
<td>3.30</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>467070.099</td>
<td>0.21</td>
<td>321</td>
<td>Re-rounded</td>
<td>1.3%</td>
<td>1.41</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>425597.8694</td>
<td>0.17</td>
<td>24</td>
<td>Re-rounded</td>
<td>1.1%</td>
<td>2.00</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>121592.4458</td>
<td>0.16</td>
<td>316</td>
<td>Re-rounded</td>
<td>1.0%</td>
<td>2.71</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>419966.4566</td>
<td>0.16</td>
<td>175</td>
<td>Re-rounded</td>
<td>1.0%</td>
<td>2.38</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>325555.1375</td>
<td>0.15</td>
<td>33</td>
<td>Re-rounded</td>
<td>0.9%</td>
<td>4.59</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>399471.0623</td>
<td>0.13</td>
<td>337</td>
<td>Re-rounded</td>
<td>0.8%</td>
<td>2.00</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>434338.2514</td>
<td>0.13</td>
<td>45</td>
<td>Re-rounded</td>
<td>0.8%</td>
<td>2.12</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>551561.8431</td>
<td>0.13</td>
<td>184</td>
<td>Cycled (2.38% Strain)</td>
<td>0.8%</td>
<td>4.01</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>474250.7626</td>
<td>0.1</td>
<td>337</td>
<td>Re-rounded</td>
<td>0.6%</td>
<td>4.36</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>368326.5377</td>
<td>0.08</td>
<td>224</td>
<td>Cycled</td>
<td>0.5%</td>
<td>3.06</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>342992.7612</td>
<td>0.01</td>
<td>284</td>
<td>Re-rounded</td>
<td>0.1%</td>
<td>0.82</td>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>605031.3181</td>
<td>0.23</td>
<td>154</td>
<td>Re-rounded (3% Strain)</td>
<td>1.4%</td>
<td>2.59</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>598349.4445</td>
<td>0.23</td>
<td>169</td>
<td>Re-rounded</td>
<td>1.4%</td>
<td>2.71</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>67242.64924</td>
<td>0.22</td>
<td>146</td>
<td>Re-rounded</td>
<td>1.4%</td>
<td>4.01</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>421639.6281</td>
<td>0.21</td>
<td>159</td>
<td>Re-rounded</td>
<td>1.3%</td>
<td>6.83</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>125388.8254</td>
<td>0.2</td>
<td>139</td>
<td>Re-rounded</td>
<td>1.3%</td>
<td>1.88</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>442481.8584</td>
<td>0.19</td>
<td>146</td>
<td>Re-rounded</td>
<td>1.2%</td>
<td>6.60</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>177901.3420</td>
<td>0.17</td>
<td>153</td>
<td>Re-rounded</td>
<td>1.1%</td>
<td>2.71</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>22890.7645</td>
<td>0.16</td>
<td>127</td>
<td>Re-rounded</td>
<td>1.0%</td>
<td>3.42</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>80958.45009</td>
<td>0.15</td>
<td>153</td>
<td>Re-rounded</td>
<td>0.9%</td>
<td>4.12</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>286447.1237</td>
<td>0.13</td>
<td>138</td>
<td>Re-rounded</td>
<td>0.9%</td>
<td>5.18</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>416568.2678</td>
<td>0.12</td>
<td>167</td>
<td>Re-rounded</td>
<td>0.8%</td>
<td>4.83</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>61980.10346</td>
<td>0.09</td>
<td>200</td>
<td>Re-rounded</td>
<td>0.6%</td>
<td>2.12</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>575503.2139</td>
<td>0.04</td>
<td>223</td>
<td>Re-rounded</td>
<td>0.3%</td>
<td>1.06</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>575499.6501</td>
<td>0.04</td>
<td>256</td>
<td>Re-rounded</td>
<td>0.3%</td>
<td>0.71</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
<tr>
<td>142072.992</td>
<td>0.02</td>
<td>231</td>
<td>Re-rounded</td>
<td>0.1%</td>
<td>0.35</td>
<td>4</td>
<td>Moderate Low</td>
<td></td>
</tr>
</tbody>
</table>
Case Study

Dig 12-0160 with 0.95% dent, gouging and cracking

SMFL

DEF

LFM

MFL
Conclusion

- Individual technologies have limitations when used independently as defined by NACE SP0102-2010

- Multiple Datasets (DEF+SMFL+MFL+RES):
  - Overcome limitations of individual technologies
  - Provide clarity of axial anomalies, and because of combination of Axial MFL with SpirALL,
  - More effectively detects and characterizes crack-like and metal loss anomalies whether seam or pipe body
  - Accurately detects and characterizes 3rd party damage for prioritization
  - Will ultimately translates into greater accuracy of results
  - Proven to eliminate unnecessary seam anomaly excavations
Thank You!

Trusted Performance / Innovative Solutions