Detection and Measurement of Pitting Corrosion using Short Range Guided Wave Scanning

Sam Horne, Eli Leinov, Tomasz Pialucha

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Abstract: Short range guided wave scanning is an inspection method enabling an indirect, quantitative measurement of remaining pipe wall thickness. It has seen widespread industrial use as an inspection solution for corrosion under pipe support (e.g. [1]). Pitting corrosion represents a significant challenge in industrial pipelines and its presence complicates short range guided wave scanning analysis as the wavelength used for inspection is larger than the diameter of small pitting-type defects. This work investigates the reflected signal from pitting corrosion, both in isolation and in the presence of larger corrosion patches, to improve the understanding of the complex signals received. This work provides the foundation and guidance for analysis techniques used in guided wave scanning. To achieve this a series of representative pitting defects with varying diameter and depth have been investigated using explicit finite element modelling. It is shown that using currently established analysis techniques, the pit depth can be quantified for pitting with a diameter larger than approximately 13 mm. Smaller diameter pitting may only be qualitatively detected at this time due to mode conversion occurring at the defect, which obscure features that are used to provide quantitative analysis of the defect depth. Quantitative sizing of defects where pitting is present will require further investigation.

Keywords: Corrosion, Inspection, pitting, Guided wave scanning

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DETECTION AND MEASUREMENT OF PITTING CORROSION USING SHORT RANGE GUIDED WAVE SCANNING

Sam Horne, Eli Leinov and Tomasz Pialucha
Guided Ultrasonics Ltd.

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OUTLINE

• Inspection challenges
• Guided wave short range scanning
• Guided wave thickness measurement
• Pitting corrosion
• Conclusions
• Q&A
Supports

Wall penetrations / Anchors

- Inaccessible areas of corrosion/erosion
- Typically where moisture collects
- Hidden when in service
- Older pipes can be obscured with multiple paint layers
- Normally direct access is the only way to reliably measure remaining wall
- Direct access to the area very costly
GUIDED WAVE SHORT RANGE SCANNING

- **Guided Wave Short Range Scanning** is a recently developed and patented ultrasonic guided wave method
- **Indirectly** measure remaining wall thickness
- Only **quantitative** inspection solution for challenges presented by inaccessible applications, e.g. Corrosion Under Pipe Support (**CUPS**)?
- Use of wave modes that are sensitive to pipe wall thickness variation
The QSR\textsuperscript{®} scanner measures at each step:

- Pipe Diameter
- Top Path Wall Thickness
- Bottom Path Wall Thickness
- Bottom Path Minimal Wall Thickness
The QSR Axial measures at each circum. step:

- Wall Thickness beneath sensor
- **Minimal Wall Thickness** from reflected signal

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GUIDED WAVE THICKNESS MEASUREMENT

Time-Frequency representation

Dispersive SH1
Non-Dispersive SH0

$f_{\text{cut-off}} \propto \frac{1}{\text{wall thickness}}$
GUIDED WAVE THICKNESS MEASUREMENT

No Loss

With Loss

Transmitter
Tx
Receiver
Rx
t0
Time

Transmitter
Tx
Receiver
Rx
t0
tMin.

Frequency [kHz]

Time

Frequency [kHz]

Time

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QUANTITATIVE GW SHORT RANGE SCANNING: THE QSR®

• Reliable and easy to use
• Automatically configures scan parameters
• Scans pipe under its own power at pre-defined step size
• Does not require the use of any couplant
• Inspects through thin coatings
• Data post-processed by Machine Learning Algorithms for accurate defect sizing (currently available for QSR1 only)
PITTING CORROSION

- Depending on the material and conditions localized pitting corrosion may be present.
- Pitting presence complicates short range guided wave scanning analysis as the wavelength used for inspection is larger than the pitting-type defect size.
- Use full 3D finite element (FE) experiments to simulate the QSR Axial setup and operation.
1) The ‘clean’ pipe case – no defect

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Steel, 10” Sch-40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom. Wall thickness</td>
<td>9.27mm</td>
</tr>
<tr>
<td>Frequency range</td>
<td>100-500kHz</td>
</tr>
<tr>
<td>Element size</td>
<td>0.3mm</td>
</tr>
<tr>
<td>Model DoF</td>
<td>800M</td>
</tr>
</tbody>
</table>
RESULTS

2) Corrosion patch

The defect:
Diameter: 127mm

Increase depth: 15-50%
RESULTS

3) Isolated pitting

The pits:

- Size: 1/8” (3.18mm) to 3/4” (19.05mm)
- Depth: 20-60%

5/8” Pit (15.87mm)

20% depth

40% depth

60% depth

Mode converted signals

Reflected SH1
3) Pitting

<table>
<thead>
<tr>
<th>20% depth</th>
<th>40% depth</th>
<th>60% depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="1/4” Pit (6.35mm)" /></td>
<td><img src="image2" alt="1/4” Pit (6.35mm)" /></td>
<td><img src="image3" alt="1/4” Pit (6.35mm)" /></td>
</tr>
<tr>
<td><img src="image4" alt="1/8” Pit (3.18mm)" /></td>
<td><img src="image5" alt="1/8” Pit (3.18mm)" /></td>
<td><img src="image6" alt="1/8” Pit (3.18mm)" /></td>
</tr>
</tbody>
</table>
RESULTS

4) Combined corrosion patch and pitting

The defect:
305mm x 152.5mm corrosion patch of 15% depth
1/2-inch (12.7mm) pits

The Axial sensor is circumferentially aligned with pit of:

- 20% depth
- 40% depth
- 60% depth

The Axial sensor is circumferentially aligned with pit of:
CONCLUSIONS

• The QSR Axial sensor provides sizing and depth measurements for corrosion patches with various profiles found in the industry.

• The presence of pitting clusters makes little difference to measurement of the majority of the remaining pipe wall thickness allowing accurate FFS calculations.

• Individual pits down to 1/2” (12.7 mm) can be quantitatively measured.

• The presence of finer pitting is indicated by the presence of mode converted signals. Individual pitting corrosion of diameter as small as 1/8” (3.2 mm) with a depth of 20% wall thickness or deeper can be detected.

• The Machine Learning developed for QSR1 (circumferential) improves analysis accuracy, reliability and provides consistent results compared to variations across different inspectors, while improving training. It will be applied to axial interpretation.
QUESTIONS?

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GUIDED WAVE THICKNESS MEASUREMENT

EMAT induced Shear-Horizontal waves traveling in the axial direction

Low frequency: only SH0 propagates

High frequency: both SH0 and SH1 propagate

Finite Element simulation

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