Practical Application of Guided Waves for Buried Piping Inspection

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Generation of Guided Waves

- Probes or sensors are installed on the component and pulsed with the GW system.
- Probes “listen” for reflected energy and convert to an electrical signal that is recorded for subsequent data analysis. Exact values are not displayed. Peaks in reflection of degradation are evaluated.
A guided wave is generated by a ring of piezoelectric transducers. The guided wave propagates down the pipe and changes in the cross-section of the pipe or stiffness create reflections. These include welds, flaws, corrosion, flanges, valves, wall thickness changes, etc. The reflections propagate back to the ring where they are received. The received signal is plotted as a function of distance from the ring. Typically welds are used as reference markers and calibration for the test. Prior to the setup, UT thickness measurements should be taken to verify pipe thickness.
Mode Shape of T(0,1) torsional mode (twisting)
Benefits of Guided Waves

- Efficient 100% volume inspection of a large section
- Can potentially propagate long lengths, although flanges and large valves act as obstructions
- Inaccessible locations including wall penetrations, buried, coated, or obstructed areas
- Limited cleaning and excavation (required at locations where transducer ring is applied), but does require removal of coating
- Does not require access to inside of pipe or cleaning of inside pipe walls
- May inspect while system is operating
- No risk of getting anything stuck or losted inside the pipe
- No risk of contaminating inspection equipment
- Potential for periodic monitoring via permanently mounting sensors
- Technology available from 2” to 96” diameter
Challenges of Guided Waves

• Thick viscous coatings attenuate signal, thus reducing effective inspection lengths and sensitivity to flaws
• Flanges are barriers for guided wave propagation – inspection beyond a flange is not possible
• Elbows distort the guided wave signal and reduce signal-to-noise making inspection beyond them difficult
• Distinguishing flaws from other nonaxisymmetric reflectors such as welded attachments
• Quantifying size of damage is often not highly accurate

Work needs to be done in these areas to study and improve GW capabilities.
Guided Wave is a screening tool

- GW is still considered mainly for screening of flaws with follow up UT or other conventional technique for verification and sizing.
- Circumferential extent of the flaw can be roughly approximated.
- Reflection amplitude can be used to qualitatively categorize a flaw into 2 to 3 categories (Severe, intermediate, not severe, etc.) but to calculate precise percentages of depth is currently not accurate.
- Flaws can be differentiated from welds by analyzing the nonaxisymmetric flexural content of the reflected signal.
24” Pipe mockup with an elbow and several flaws – elliptical dishes and flat-bottom holes
Flaws in 24” Pipe Mockup

Flaw #1 – 3” x 1” (50% thru-wall)

Flaw #2 – 2” x 1” (50% thru-wall)

Flaw #3 – 1” dia. flat-bottom holes (50% thru-wall) set of 3 – 1 ft. apart

Flaw #4 – 6” x 1” (50% thru-wall)
Unrolled pipe display helps estimate circumferential location and extent
Focusing can be used to determine the relative circumferential extent of a flaw

<table>
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<th>Focusing Result</th>
<th>Test Frequency</th>
<th>Wave Mode</th>
<th>Test Direction</th>
<th>Focal Distance</th>
<th>Distance from datum</th>
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<td>30kHz</td>
<td>Torsional</td>
<td>Backwards</td>
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<td>Torsional</td>
<td>Forward</td>
<td>18.82ft</td>
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</tbody>
</table>

Flaw #1

Flaw #2

Flaw #3

1st Elbow Weld
GW data with MsS sensor at right end of pipe

MsS sensor
Reverberation
End of Pipe

Weld
Bend Weld
Bend
Weld

Flaw #1
MsS Strip

Flaw #2
Flaw #3
Flaw #4
Coatings have a significant effect

- Most important is bonding condition
  - Degraded or disbonded coatings may cause little attenuation
  - Material properties of coating – viscous coating will absorb sound; soft – high attenuation, hard – low to medium attenuation
  - Thickness of the coating – thicker means more absorption
- Thin uniform coatings such as paint (less than 10 mils) do not cause much attenuation
- Environmental conditions have strong effects as well
  - Temperature, aging, cracking, drying out
GW Data from Pritec coated Pipe 1 with native clay backfill shows a reflection from a flange at about 40'
GW Data from Pritec coated Pipe 3 with pea gravel backfill shows a reflection from a flange at about 80’
Data on mockup with different backfills shows significant effects on inspection lengths

- Pea gravel – least attenuative (40-50 ft. inspection range)
- Native clay – inspectable, but shorter inspection length than pea gravel (20 - 30 ft. inspection range)
- Portland cement – very difficult to inspect, (< 10 ft. inspection range)
Field samples were received that had been in service for 35 years

- Coating had completely failed along nearly the entire length of piping except for a few blotches
- General corrosion and pitting with varying severity along the length
- We need to quantify the actual severity of the general corrosion on each pipe
Guided Wave Attenuation of pipes removed from service correlates to the surface roughness

Pipe 1
Least severe corrosion

Pipe 2
Intermediate severe corrosion

Pipe 3
Most severe corrosion
Pipe with coal tar epoxy and tuberculation