Long Ultrasonic Guided Waves for Pipelines Inspection

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Abstract

The operation consists of an application of ultrasonic waves to pipes in order to detect metal loss and other defects in the pipe wall due to corrosion and other degradation processes. These waves are transmitted along the pipe by rings of piezoelectric transducers attached to the outer or inner surfaces. Defective areas produce reflections which are picked up by the transducer so that defects can be detected.

The properties of most guided waves are dependent on the wave frequency, the pipe thickness and to a lesser extent, the pipe diameter.

Theoretical modelling is key to understanding the fundamental mechanisms, but also to visualise its acoustic behaviour, for example, the field pattern generated in the material and to aid the interpretation of received signals. COMSOL Multiphysics® simulation software has been used to study the behaviour of guided waves in the PIGWaves project. A transient regime model allows:

• Generate numerical FEA.
• Couple Elasto-dynamics with electro-magnetics.
• Use FFT to extract the frequency content from the A-scans.
• Use 2D FFT to identify the content of the extrusion plots (A-scans at different positions) with regards to frequency/space.
• Show how discontinuity (defect) will affect the wave propagation.
• Show the effect of the remaining thickness on the mode conversion.

In order to understand the results, the basic behaviour of the guided waves and its propagation has to be known. Figure 1 shows guided waves propagation as follows:

• GW transmitted at the sensor location on the inner surface of the pipe.
• GW travels in both directions until it reach the pipe end.
• GW reflected and echoes are sent back to the sensors.

Figure 1 Guided waves propagation.

By increasing the number of sensors, the separate excitations are reinforcing the axi-symmetry of

the excitation. Extrusion plots represent a cross-sectional profile of the wave propagation along the pipe. All simulation scenarios show one reflection at the end of the pipe (2.5m). Pipe ends are axi-symmetrical features and are 100% reflectors. This is due to the large difference in acoustic impedance between the pipe and the air.

Figure 2 Extrusion plots comparison. 8, 16 and 32 transducers.

On ultrasonic flaw detectors, an A-Scan display shows the amplitude of received signals versus distance from the transmitting transducer. The A-Map is a 3D display of the ultrasonic responses from the pipe. It shows the amplitude of the signals received and the angular position around the circumference and its distance.

Ultrasonic vibrations may occur in different directions (see Figure 3). The combination of vibrations in the 3 orthogonal directions gives rise to different wave modes, each with different characteristics.

Figure 3 Example of A-Scan.

Figures used in the abstract

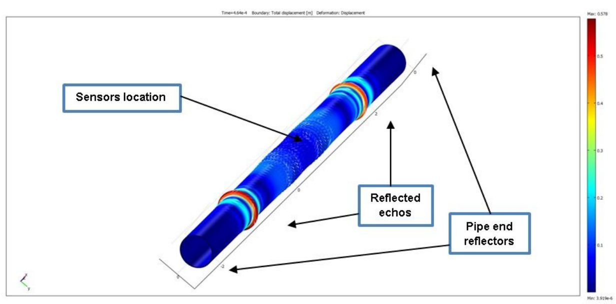

Figure 1: Figure 1 Guided waves propagation.

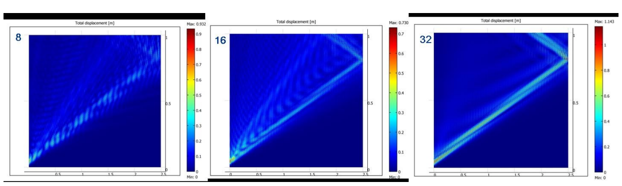

Figure 2: Figure 2 Extrusion plots comparison. 8, 16 and 32 transducers.

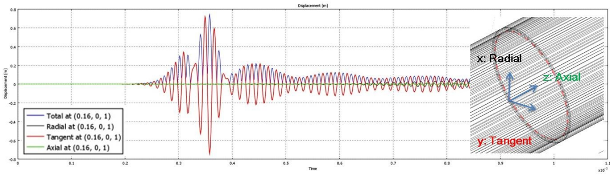

Figure 3: Figute 3 Example of A-Scan.