# DEFECT DETECTION AND SIZING IN PIPES USING TORSIONAL GUIDED WAVES

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## 1. The inspection system

Long pipelines are often used in petro-chemical industry for transporting liquid and gaseous substances. These pipes need to be regularly monitored and inspected for both safety reasons and environmental impact control. Guided waves have been increasingly used in nondestructive evaluations. Many researchers have been interested in the application of ultrasonic guided waves for the nondestructive inspection of pipes [1, 2, 3]. Axisymmetric modes are preferred for the detection of defects in pipes. Among these waves, the torsional one T(0,1) is the only one whose velocity remains constant with frequency. All the others suffer speed variations as the frequency changes which is a major disadvantage for wave generators that could only generate longitudinal or flexural waves. Besides, it keeps its speed constant and it propagates through pipes filled with liquid without much leakage.

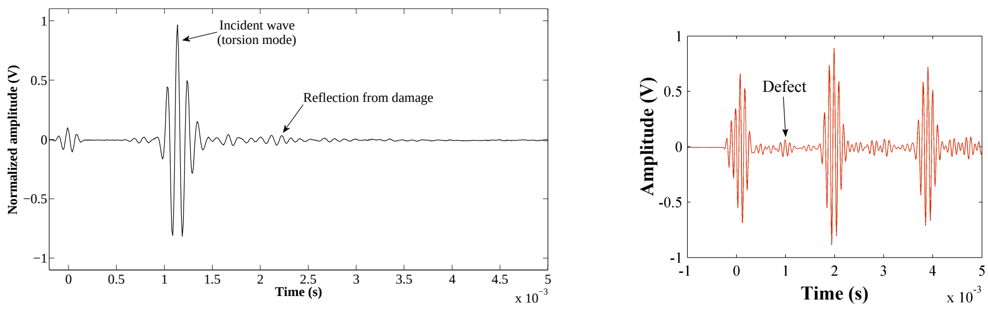
In this work, an inspection system has been designed and developed to excite the pipe under test with well-defined waves that propagate along the structure; and also to receive reflected signals from features and damages encountered. The torsional mode was chosen to be generated by the system. The generation of torsional waves is operated by using a number of piezoelectric transducers clamped around the circumference of the pipe. The design process of the torsional waves inspection system is presented. Time responses were examined for intact and damaged pipes. Then, experimental tests have been performed on two pipes with different materials: PVC and steel. Some defects have been machined on these pipes. Their interaction with torsional waves has been proven by analyzing experimental time responses. Subsequently, the Wave Finite Element Method (WFEM) has been used to construct a database of reflection coefficients from a rectangular defect with variable axial, circumferential and thickness extents. Calculations was made depending on the excitation frequency with the torsional mode T(0,1) as incident wave. This aims to approximate defect sizes that were already detected.

## 2. Experimental tests

The actuator and the sensor are mounted on a straight 3 m-long, 5 mm-thick, 140 mm outer diameter PVC pipe without any defect. The actuator is attached at one end of the pipe; the sensor is placed at 1 meter from the actuator. Fig. 1(a) shows the time record for a pipe with a defect. This defect is a single 60 mm radial cut. It is located half way from both ends of the pipe. When a 3m-long steel pipe is used, the wave can travel back and forth, reflecting itself several times at each end of the pipe. This effect is visible on Fig. 1(b), with the same kind of pulse as for the previous example.

## 3. Defect sizing by WFEM

The Wave Finite Element Method (WFEM), which is a simple spectral method based on the standard finite element (FE) formulation, can be applied to examine the wave interaction with the local defects and the structural features [4, 5]. To approximate the size of the defect, the idea was to build a digital database containing the different probabilities of defect sizes that could exist while assuming that it was modeled with a form similar to that shown in Figure 2. The parameters that characterize the defect are '$a$, $b$, $c$', which are axial extent, depth, and circumferential extent respectively. Calculations was made by varying these three parameters. The axial extent sweeps the interval [4-20] mm in steps




(a) (b)

**Figure 1.** Time signal recorded : (a) from damaged PVC pipe, and (b) from damaged steel pipe.

of 4 mm. The circumference of the pipe was divided to 44 elements, the circumferential extent was varied by eliminating an element in every step. Knowing that the pipe diameter is of 168 mm, each element measures 12 mm in the circumferential direction. Finally, the depth of the defect varies from 2 mm with a step of 3 mm until the whole pipe thickness which is 11 mm. Reflection coefficients calculation was made depending on the frequency in the range [5-15] kHz. This latter corresponds practically to the signal frequency at which the pipe under test was excited. The torsion mode was considered in the calculation process.

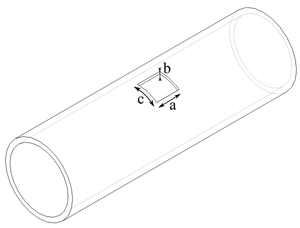



**Figure 2.** Damaged pipe with defect dimensions.

## 4. References


[1] J.L. Rose. A baseline and vision of ultrasonic guided wave inspection potential. *Transactions-American society of mechanical engineers journal of pressure vessel technology*, 124(3):273–282, 2002.

[2] RB Thompson, GA Alers, and MA Tennison. Application of direct electromagnetic lamb wave generation to gas pipeline inspection. In *1972 Ultrasonics Symposium*, pages 91–94. IEEE, 1972.

[3] MG Silk and KF Bainton. The propagation in metal tubing of ultrasonic wave modes equivalent to lamb waves. *Ultrasonics*, 17(1):11–19, 1979.

[4] M.N. Ichchou, J.-M. Mencik, and W. Zhou. Wave finite elements for low and mid-frequency description of coupled structures with damage. *Computer Methods in Applied Mechanics and Engineering*, 198(15-16):1311–1326, 2009.

[5] W.J. Zhou and M.N. Ichchou. Wave propagation in mechanical waveguide with curved members using wave finite element solution. *Computer Methods in Applied Mechanics and Engineering*, 199(33-36):2099–2109, 2010.