Passive guided waves tomography for structural health monitoring of pipes

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PASSIVE GUIDED WAVES TOMOGRAPHY FOR STRUCTURAL HEALTH MONITORING OF PIPES

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ABSTRACT

Corrosion in pipes is a problem faced in several domains, like the oil and gas or nuclear industries, due to the risk of rupture or leakage. Non-Destructive Testing (NDT) techniques using elastic guided waves have proven useful to detect such defects due to their ability to interrogate large structures and their sensitivity to defects. More recently, Structural Health Monitoring (SHM) approach seeks to implement permanently attached sensors over the structure lifetime. Elastic guided waves tomography can reconstruct a thickness map of the structure over a large zone with a reduced number of transducers, and thus localize and characterize corroded areas. Tomographic algorithms are well suited for a passive approach, without wave excitation. In that case, sensors only measure the ambient elastic noise present in the operating structure (due to flow, vibrations…). The cross-correlation of these signals allows getting the same information as with measurements from active sources. Passive process has been demonstrated in plate-like structures. This paper shows experimental results of corrosion imaging in pipes using passive tomography. The passive approach is a path forward for using optic fibers with Fiber Bragg Grating (FBG) instead of piezoelectric transducers, offering a lighter, less intrusive and more permanent solution.

KEYWORDS: Guided Waves, Tomography Imaging, Piezoelectric sensors, Fiber Bragg Grating (FBG), Pipe-like Structures, Corrosion

1. INTRODUCTION

Many industries have to face erosion and corrosion problems in pipes. The SHM process aims at interrogating the state of health of a structure during its lifetime with an attached instrumentation.

Tomography techniques using elastic guided waves have proven useful to detect and locate damages [1]. Most of the time the SHM system implies the use of piezoelectric elements. Unfortunately, this type of sensors does not resist extreme conditions (*e.g.* high temperature), adds weight to the structure and their use as actuators necessitates heavy cabling. Optical fibers with FBG are a good alternative [2], but can only be used as receivers and not transmitters. Passive methods seeks to achieve the same results as with active sources, but without them. They rely on extracting information from the ambient noise of the structure, which also carries waves. For instance, a structure, during its service, can undergo several vibrations: air turbulence for a plane, turbulent fluid in a pipe, vibrations caused by engines…

This abstract quickly reminds the passive tomography imaging principle, shows experimental results on a pipe using two arrays of PZT, then compare the active and passive approaches to detect a corrosion defect. It then discusses on the use of FBG.

2. PASSIVE TOMOGRAPHY

Guided wave tomography imaging process consists in surrounding the monitored area with a distribution of sensor and measuring the responses between all the different possible couples of sensors. The collected data are then inverted to produce a thickness map of the area. Several assumptions are necessary to choose a propagation model for tomography.

Assuming that the wall thickness is small regarding the pipe radius, the propagation of guided waves can be modeled by a phase velocity field that depends only on the wall thickness and not the direction, thus the acoustic model can be used in this case. The tomography can then be implemented by unwrapping the pipe and treating it as a flat plate [3].

The passive method uses cross-correlation on the random field (ambient noise) measured simultaneously at two points, to reconstruct the information of propagation between them. Passive method exploits the presence of ambient noise in the structure, *e.g.* the flow of fluids inside pipes or the structure vibrations. The idea comes from the geophysics domain [4]. The relationship between the cross-correlation and the Green's function has been established in several articles such as [5]. The passive measurement between two points A and B consists in simultaneously measuring the ambient elastic noise in A and in B. Under certain conditions, the cross-correlation of these signals allows obtaining Green's function between A and B. The tomography can then be applied using signals correlated from ambient noise at different measuring points and the resulting passive signals are then used as an input data for tomography algorithm as described in [6] in order to reconstruct thickness map.

3. RESULTS

The considered configuration consists in a 2.15 mm thin, 254 mm outer diameter steel pipe instrumented with two arrays of 15 PZT sensors. An area is artificially corroded, and an optical scan was done to know the exact thickness. The results of the tomography are displayed in Figure 1. The reference thickness map is presented in Fig.1(a), and imaging using either active or passive methods are respectively in Fig.1(b) and Fig.1(c). Both methods are able to correctly locate and estimate the global shape of the corrosion defect. Minimal remaining wall thickness is correctly captured, which is the most important information for safety.

(a) (b) (c)

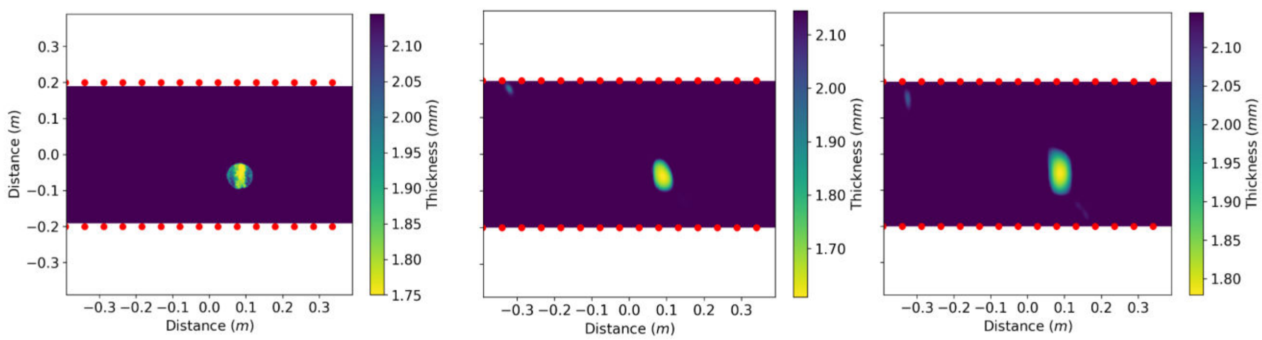

Fig. 1 (a) real thickness map, (b) active imaging and (c) passive imaging of a corrosion defect in a pipe.

4. TOWARDS THE USE OF FBG

Passive wave measurements with FBG sensors is also possible with noise cross-correlation [2]. The next step is to obtain the same results as with piezoelectric elements using arrays of FBGs and obtain maps similar to results of Fig. 1. Some challenges need to be faced, such as the FBG directivity. So far, first results have been obtained using active hybrid tomography with one ring of piezoelectric transducers and one ring of FBG [7].

5. CONCLUSION

This paper have briefly presented the active and passive tomography for corrosion or erosion detection. The obtained results for both active and passive cases are in agreement with the defect real location and size. Future works will specifically focus on the implementation of optical fiber Bragg grating sensors to reduce the intrusiveness of sensors in the SHM system. Encouraging results let envision the use of such an SHM system in harsh environment (radiations, high temperatures, explosive atmosphere).

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