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Review

Pattern recognition by wavelet transforms using macro fibre composites transducers

Raúl Ruiz de la Hermosa González-Carrato [a,*], Fausto Pedro García Márquez [b], Vichaar Dimlaye [c], Diego Ruiz-Hernández [a]

[a] CUNEF-Ingenium Research Group, Colegio Universitario de Estudios Financieros, Madrid, Spain
[b] Ingenium Research Group, University of Castilla-La Mancha, Ciudad Real, Spain
[c] NDT Technology Group, TWI – Technology Engineering, United Kingdom

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ABSTRACT

This paper presents a novel pattern recognition approach for a non-destructive test based on macro fibre composite transducers applied in pipes. A fault detection and diagnosis (FDD) method is employed to extract relevant information from ultrasound signals by wavelet decomposition technique. The wavelet transform is a powerful tool that reveals particular characteristics as trends or breakdown points. The FDD developed for the case study provides information about the temperatures on the surfaces of the pipe, leading to monitor faults associated with cracks, leaks or corrosion. This issue may not be noticeable when temperatures are not subject to sudden changes, but it can cause structural problems in the medium and long-term. Furthermore, the case study is completed by a statistical method based on the coefficient of determination. The main purpose will be to predict future behaviours in order to set alarm levels as a part of a structural health monitoring system.

Contents

1. Introduction

The transport technology for gas and liquid elements is rising nowadays. Pipe degradation is induced by corrosion, decreasing the thickness of the pipe wall. Internal (material, shape, age, etc.) and external (temperature, weather

* Corresponding author.
E-mail addresses: raulruiz@cunef.edu (R. Ruiz de la Hermosa González-Carrato), faustopedro.garcia@uclm.es (F.P. García Márquez), vichaar.dimlaye@twi.co.uk (V. Dimlaye), d.ruiz@cunef.edu (D. Ruiz-Hernández).

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or pressure) conditions lead the structural deterioration. The temperature is a key factor that affects to corrosion and erosion [36]. Temperature changes are responsible for the detachment of pipe material, e.g. copper [45].

Pipelines require regular inspections to restore the damage and to replace the structure when it is inappropriate for operation [11]. Fault detection becomes a complicated task when pipelines are located in inaccessible places [8,35]. Traditional inspection may be accurate, but depends on training and other human factors, and have a detection threshold where corrosion is not measurable [46]. Automated systems have the advantage of reducing the human intervention, and help the worker to make decisions [26]. Any maintenance program should include monitoring of pipes among their objectives [5]. Erosion, corrosion and leakage may also represent hazards to pumps or valves that are connected to them.

The collection and analysis of data is the first step for a structural health monitoring (SHM) of pipes. Techniques include non-destructive tests (NDT) for condition monitoring. Different types are usually combined to provide more information about the status and characteristics of the structure under consideration [34]. Some of these methods are widespread e.g. visual inspection, but many others emerge slowly due to the necessity of highly skilled users controlling the equipment [40].

Thus NDT has become an essential tool during the lifecycle of many structures based on, for example, ultrasound signals or self-sensing impedance methods to detect structural damage in the joints of pipelines, while Lamb approaches identify cracks and corrosion along the surface [51]. In the field of acoustic emissions (AE), the online monitoring starts to be relevant and this type of NDT is used to detect micro cracks, delamination, fibre breaks in specific structures [4]. Therefore, monitoring pipelines from NDTs is a recurring topic in the literature, but the researches tend to relate factors such as corrosion or fractures to stress situations [19]; and not many authors study the performance of the temperature [33].

This paper introduces the wavelet methodology for the analysis of temperature using sensors based on macro fibre composites (MFC). There are not case studies using MFC transducers for the pipelines monitoring that link ultrasound and temperature, even when it has been shown that the use of certain transducers (electromagnetic acoustic transducers) is effective in the detection of corrosion and cracks if the results are discussed with the wavelet transform. It is also known that these sensors are sensitive to specific temperatures [32], and their strategic placement assures the monitoring of complex or inaccessible structures.

The case study attempts to verify that the ultrasonic signal provides information about the behaviour of the pipe from the temperature and the relation to structural changes. This issue may not be noticeable when the temperature is not subject to sudden changes, but it can cause structural problems in the medium and long-term.

Section 2 provides an overview of the MFC and Section 3 introduces the wavelet transform. Section 4 describes the case study, the techniques deployed, the pattern recognition method and the remarkable results. Finally, the last section presents the conclusions.

2. Macro fibre composites

There are different types of composites commercially available, e.g. metal matrix composites [12], ceramic matrix composites [38], active fibre composites [9] or MFCs. MFC is a polymeric matrix made of piezoceramic fibres (see Fig. 1) embedded between phases of adhesive film with electrodes that transfer voltage to ribbon-shaped rods and vice versa [14]. MFC is a composite technology originally developed at the NASA Langley Research Center (United States).

MFCs present a piezoelectric behaviour when there is a transformation of electronic impulses into ultrasonic waves. The impulses can turn into a voltage signal by pressure changes. By applying the voltage difference between the interdigitated

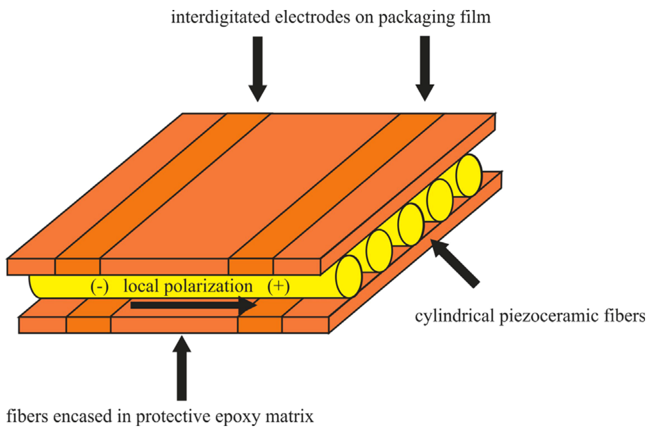

Fig. 1. Section of the structure of a generic piezoceramic fibre composite.