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Non-destructive evaluation of anchorage zones by ultrasonics techniques

M. Kharrat *, L. Gaillet

Institut Français des Sciences et Technologies de Transport, de l'Aménagement et des Réseaux, Département Matériaux et Structures, Laboratoire Structures Métalliques et à Câbles, Route de Bouaye, CS4, 44344 Bouguenais Cedex, France

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ABSTRACT

This work aims to evaluate the efficiency and reliability of two Non-Destructive Testing (NDT) methods for damage assessment in bridges' anchorages. The Acousto-Ultrasonic (AU) technique is compared to classical Ultrasonic Testing (UT) in terms of defect detection and structural health classification. The AU technique is firstly used on single seven-wire strands damaged by artificial defects. The effect of growing defects on the waves traveling through the strands is evaluated. Thereafter, three specimens of anchorages with unknown defects are inspected by the AU and UT techniques. Damage assessment results from both techniques are then compared. The structural health conditions of the specimens can be then classified by a damage severity criterion. Finally, a damaged anchorage socket with mastered defects is controlled by the same techniques. The UT allows the detection and localization of damaged wires. The AU technique is used to bring out the effect of defects on acoustic features by comparing a healthy and damaged anchorage sockets. It is concluded that the UT method is suitable for local and crack-like defects, whereas the AU technique enables the assessment of the global structural health of the anchorage zones.

1. Introduction

Upon commissioning, civil engineering infrastructures, like bridges, are subjected to multiple aggressive conditions. Generally, the older the bridge is, the higher the risk of disorder. Most degradation mechanisms are currently known and have been reported in several works [1–5]. Corrosion and fatigue are the main causes of damage and have often a harmful combination on the health condition of bridges. In the most critical cases, the damaged bridge's components must be replaced.

Among the major bridge's components, cables and anchorage zones could be subjected to hard solicitations. Cables are primarily undergoing environmental aggressions. Run-off water added with deicing salts could penetrate in cables and gravitationally flow toward tightened areas (ties of suspension lines) or toward lower zones (such as anchorages). This confined humidity often engenders corrosion. Non-alloy steel used in cables is sensitive to corrosion by dissolution, so that a section loss more or less homogeneous can affect all or part of the wires constituting cables and can decrease their breaking strength [6,7]. Moreover, fretting-fatigue mechanism produces small relative displacements between the wires of a single cable (inter-wires contact), between neighboring cables, or also between a cable and other fixed parts like anchorages. This can cause wear and/or cracking of the wires [8,9]. As the anchorage zone is an inaccessible part of the bridge and is located at the bottom of the retaining cables, it provides an ideal place for water accumulation and promotes corrosion development. The major problem here is the rupture of wires that cannot be anticipated by visual inspections. This bridge's component requires the implementation of operational inspection techniques able to assess its structural health and prematurely detect damages before the failure of the whole structure [10,11].

Regarding Non-Destructive Testing (NDT) of civil engineering structures, an important distinction is commonly made between accessible and inaccessible parts. Accessible parts relate to components where the element to be inspected is directly visible and easily accessible; while inaccessible parts involve hidden components of the structure, so that require a prior intervention before inspections. If the current state-of-the-art of monitoring techniques of accessible parts is based on visual inspection [12], magnetic inspection [13], and acoustic monitoring [14,15], that concerning inaccessible parts is still missing. The inspection and monitoring of inaccessible areas are of major concern as they are often considered as the weakest parts where fatigue and corrosion

* Corresponding author at: Department of Applied Mechanics, FEMTO-ST Institute, Franche-Comté University, 25000 Besançon, France. Tel.: +33 682212604.
E-mail address: mohamed.kharrat@femto-st.fr (M. Kharrat).

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mechanisms can appear. However, many structural factors can greatly complicate their inspection. Key factors mainly include the influence of different material layers and multiple interfaces in protection systems of cables embedded in anchorages and suspension collars. Furthermore, various techniques have been studied among which ultrasonic guided waves [16,17], magnetic flux leakage inspection [18], micro-magnetic methods, and acoustic emission monitoring [19] seem to be suitable. The Acousto-Ultrasonic (AU) is a relatively new technique in civil engineering. It has been initially used for inspection and characterization of graphite-reinforced plastics (GRP) [20–22]. Acousto-Ultrasonic parameters (AUPs) have shown a good correlation with the mechanical strength for both tension and compression test configurations [23] and even for detecting corrosion evolution in coatings of aircraft wings [24]. This technique has been also used for non-destructive quantitative characterization of residual impact strength of polyvinyl chloride (PVC) using the AUPs [25]. Detection of pre-machined defects on a metal plate has been studied using a broadband excitation through temporal, frequency and wavelet analyzes [26]. Correlation between the amount of artificial defects in bonded regions and AUPs in adhesively bonded joints of carbon-fiber reinforced plastic (CFRP) laminates and aluminum plates has been also investigated [27]. However, this technique has been rarely used for damage characterization in metallic cables. This work aims to test the reliability of two NDT methods for damage assessment in some bridge's parts. Specifically, the Acousto-Ultrasonic technique is compared to classical Ultrasonic Testing (UT) technique in terms of defect detection and structural health classification.

Fig. 1. UT instruments: Krautkramer's USM25 pulser/receiver device (on the left); and SMWB70-6 probe (on the right).

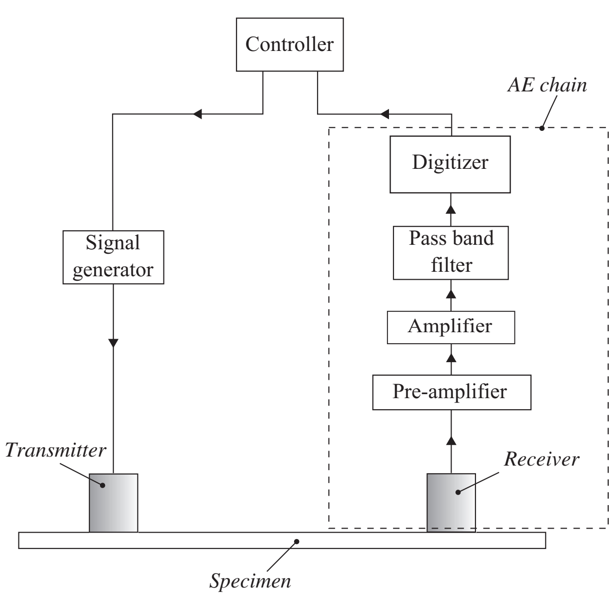

Fig. 2. Acousto-Ultrasonics principle.

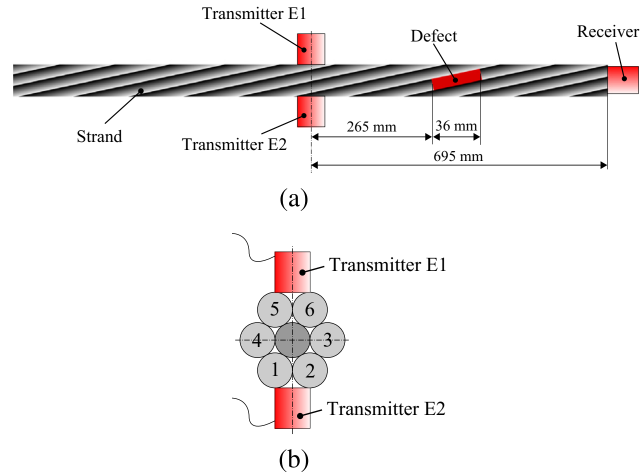

Fig. 3. Acouto-ultrasonic test performed on a single strand using two transmitters E1 and E2 and a receiver R. (a) Lateral view; (b) sectional view.

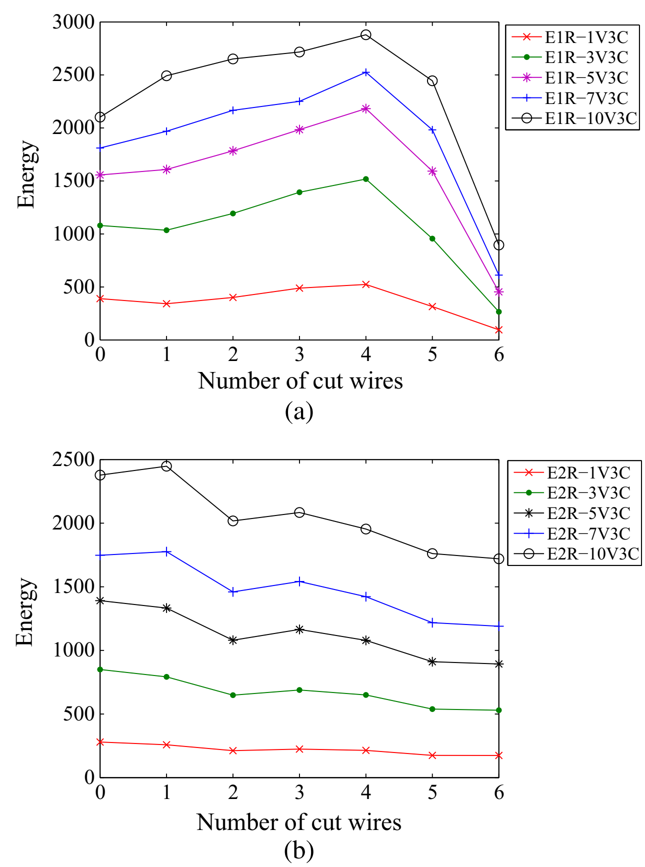

Fig. 4. Evolution of the average energy depending on the defect expansion while exciting by different waveforms. (a) Waves emitted by E1; (b) waves emitted by E2.