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Improved monitoring of acoustic emissions in concrete structures by multi-triggering and adaptive acquisition time interval

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ABSTRACT

Damage evaluation by Acoustic Emission (AE) signals is a promising technique for the non-invasive and continuous monitoring of concrete structures. The triggered acquisition modality is adopted in order to reduce the amount of acquired data in continuous monitoring. However, two main inconveniences can occur: either loss or partial acquisition of AE signals. Propagation can attenuate the signal below the trigger level causing signal loss, while the occurrence of multiple AE events can cause the loss or partial acquisition of signal due to the unpredictability of the Acquisition Time Interval (ATI). In fact, lower trigger level and wider ATI are not valid solutions in all real contexts. The proposal of the paper consists in the introduction of the multi-triggering acquisition modality and adaptive evaluation of the ATI, with the proper hardware Logic Flat Amplifier and Trigger (L-FAT) generator block designed and pointed-out to this purpose. As an evolution of the previously pointed out FAT, it generates the logical trigger whatever the transducer detecting the AE signal and adapts the ATI to the width of the multiple AE events as a further improvement. The adaptive evaluation of the ATI is based on the property that the AE length in concrete is well established. This property is used to foresee the end of the last AE by restarting the countdown at each trigger condition. The hardware architecture, the operative modality and the actual realization of the L-FAT are presented. Experimental tests assess the effectiveness of the L-FAT to monitor all the AE events, reducing the amount of acquired data, and to improve the damage evaluation of concrete structures.

1. Introduction

Non-Destructive Tests have been proposed to evaluate the damage to concrete structures [1–3]. They use techniques based on radiations [4], high electromagnetic fields [5], chemical substances [6], and ultrasonic waves [1,3,2]. The latter use the echo of the reference signal propagating into a structure to detect imperfections or to locate changes in material properties, and permit operation without hazard to operators. The use of a reference signal makes Ultrasonic Testing (UT) unsuitable for continuous monitoring due to the requirement of continuous ultrasonic waves supply and the reduced monitored area covered by the transmitter–receiver [1,3,2].

An evolution of UT is the Acoustic Emission (AE) Test [7–10]. AE Test uses the AE signals generated by the rapid release of energy from localized sources within concrete during the loading of the structures [11,12]. The absence

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of reference signal permits continuous in service monitoring but introduces the problem of signal loss. Indeed, the non-homogeneous concrete structure and the unpredictable damage modality influence AE signal propagation and attenuation. The signal could reach the receiver transducer with low amplitude undetectable by the Data AcQuisition (DAQ) system.

A valid solution to reduce the probability of signal loss is the use of multiple receiving transducers [11]. This solution reduces the surface to be monitored by each transducer and the path between the source of the AE and the receiver transducer. Consequently, the signal attenuation is also reduced.

Nevertheless, the use of multiple transducers greatly increases the amount of acquired data making their storage and elaboration difficult. In order to overcome this inconvenience, the triggered acquisition modality is adopted [12]. The DAQ system starts once the AE signal exceeds the trigger level and stops at the end of the established Acquisition Time Interval (ATI). The trigger level and the width of the ATI are settled on the basis of the amplitude and width Δt_{signal} of the AE signal [13,14].

Nevertheless, some experimental conditions can occur making the correct monitoring of all the events not assured. Indeed, some AE events can occur far away from the transducer selected as the trigger, i.e. Transducer#3 in Fig. 1 and, according to the signal propagation attenuation, the AE signal can reach Transducer#3 with amplitude lower than the trigger level. In this case the event is not monitored.

Moreover, if multiple delayed events occur in the same ATI, the first one that starts the DAQ system is correctly monitored, and according to the width of the ATI (Fig. 2), the other ones can be partially detected on the basis of their delay with respect to the first one.

Both the missing and the partial acquisition of AEs, as in the case of the AE signal#2 in Fig. 2, misstates the evaluation of the concrete damage. Indeed, the damage evaluation indexes are strongly related to the cumulated number of hits [11,14], i.e. the number of peaks evaluated in each AE signal (Fig. 2). As a consequence, the missing or the partial acquisition of AEs would cause underestimation of the damage, especially when the structure is more stressed and the AE occurrences are more frequent [11,14].

A valid solution to reduce the amount of signal loss was presented in [15]. The Flat Amplifier and Trigger (FAT) generator block was added to the traditional architecture of DAQ system. The FAT was designed to generate the trigger if one or more signals among those detected by the transducers exceed the trigger level.

This paper proposes further improvement to prevent the partial acquisition of AE signals. In particular, to the FAT architecture proposed in [15] is added the Logic Width

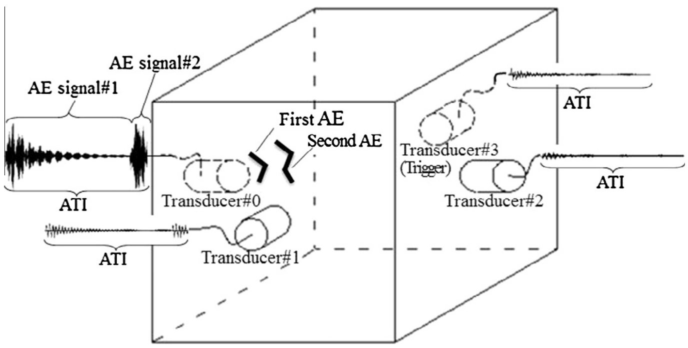

Fig. 1. Only Transducer#0 detects the AE signal due to the propagation attenuation in concrete.

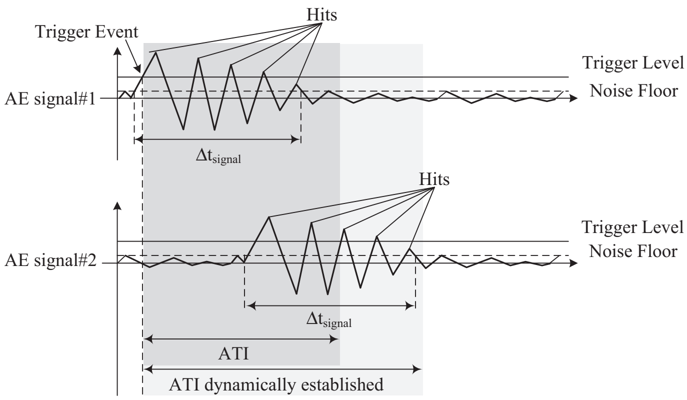

Fig. 2. AE signal#2 is partially acquired, owing to the delay with respect to the AE signal#1 and the fixed width of the ATI.