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INTEGRATING THREE INSPECTION/MONITORING METHODS FOR CIVIL ENGINEERING APPLICATIONS

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ABSTRACT

In this paper an integrated nondestructive evaluation / structural health monitoring (NDE / SHM) system based on the use of acoustic emission (AE), electromechanical impedance (EMI) and guided ultrasonic waves (GUWs) is presented. The system is integrated into a single hardware/software unit and is driven by a few graphical user interfaces created in laboratory. The feasibility of this multi-modal monitoring approach is assessed by monitoring an aluminium plate with an array of six wafer-type piezoelectric transducers. AE events are generated with the pencil-lead break technique whereas damage is simulated in the form of permanent magnets attached to the plate. The waveforms associated with the AE are processed using a source localization approach, whereas the GUWs and EMI data are processed using simple metrics based on cross-correlation. The results presented here show that the proposed system is robust and the three NDT methods complement each other very well.

Keywords: structural health monitoring, acoustic emission, guided ultrasonic waves.

INTRODUCTION

The nondestructive testing methods of acoustic emission (AE), guided ultrasonic waves (GUWs), and electromechanical impedance have been proposed and applied in a wide variety of engineering structures. The first method relies on the propagation of transient elastic waves generated by the rapid release of energy from a localized or multiple sources within the material being monitored. The waves are detected by one or more AE sensors and processed by commercial proprietary hardware and software. Some researchers proposed alternative platforms and software whereas others used sensing systems different than the commercial AE transducers, including wafer-type Lead-Zirconate-Titanate transducers (PZT). GUW-based methods rely instead on the active generation of ultrasonic signals to inspect large areas from a single or a few positions. When the method is targeted for permanent monitoring, PZT patches are used. The EMI method instead exploits the relationship between the electrical impedance of a PZT and the mechanical impedance of the host structure to which the PZT is bonded or embedded.

In this article, we present a system that integrates the three methods into a single unit. The article follows-up some early works, (Zhu and Rizzo, 2012), (Gulizzi, Rizzo *et al*., 2015) and recent findings (Nasrollahi, Deng *et al*. 2018), by our research group. In (Zhu and Rizzo, 2012) we integrated the EMI and the GUW in a pitch-catch configuration; the system was proved in a pipe and in a very large plate using two PZTs. In (Gulizzi, Rizzo *et al*., 2015) we improved the signal processing and added the pulse-echo capability, whereas in (Nasrollahi, Deng *et al*. 2018) we (1) added AE, (2) used six PZTs instead of two, (3) processed the ultrasonic data to map the area of the structure bounded by the array and (4) quantified the repeatability of the EMI method. With respect to (Nasrollahi, Deng *et al*. 2018), the present article investigates the ability of the integrated system at detecting defects outside the area bounded by the array and proved even further the advantages of integrating three methods under a single unit.

RESULTS AND CONCLUSIONS

We monitored a 1219 × 1219 × 2.54 mm3 aluminium plate by bonding six 10 × 10 × 2 mm^3 PZTs. Each PZT was located 305 mm away from the center of the plate (Figure 1). To avoid irreversible damage, the AE portion of the integrated system was proven using the pencil lead break (PLB), whereas the active GUWs and EMI methods were proven by mimicking damage with two permanent Alnico U-shaped magnets. The attraction of the magnets produced a localized compressive force on the surface of the plate at eleven locations. The PZTs were driven by a PXI unit running under proprietary software. The PXI included an arbitrary waveform generator (AWG), an 8-channel digitizer, a controller, and a simple auxiliary circuit designed in the lab. The AWG produced a chirp signal that was 10 ms long, 1,200 cycles, 24 Vpp, and frequency range 90 - 210 kHz.

This study demonstrated that PXI unit was capable of running simultaneously the methods of AE, GUWs, and EMI and to detect the location of the mimicked damage. The overall idea behind this research is that during normal operation the unit works in a “standby” mode where the acoustic emission approach passively detects the onset or the growth of new or existing damage. After determining the whereabouts of the acoustic source, the unit is switched into the active mode to quantify and tentatively size the amount of damage by one or more of the following: EMI, pulse-echo mode GUWs, or pitch-catch GUW mode. The EMI approach is suitable to identify the presence of damage very close to the PZTs; the pulse-echo can detect features that are not too-close not too-far from the wave actuators; finally, the pitch-catch mode can determine the presence of damage along and near the line of sight between actuator-sensor pairs of the array. If the system has not detected any AE event, it can always be turned into the active mode to survey the structure being monitored.

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REFERENCES

[1] Gulizzi, V., P. Rizzo, A. Milazzo and E. L. M. Ribolla (2015). "An integrated structural health monitoring system based on electromechanical impedance and guided ultrasonic waves." Journal of Civil Structural Health Monitoring 5(3), pp. 337-352.

[2] Nasrollahi, A., W. Deng, Z. Ma and P. Rizzo (2018). "Multimodal structural health monitoring based on active and passive sensing." Structural Health Monitoring, an International Journal, in press.

[3] Zhu, X. and P. Rizzo (2012). "A unified approach for the structural health monitoring of waveguides." Structural Health Monitoring 11(6), pp. 629-642.