Submitted to the 15th international conference on adaptive structures and technologies, Bar Harbor, Maine, 25-27 October, 2004 on the topic of integrated damage detection and structural health monitoring.

Instantaneous Damage Detection using Time Reversal Process

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A damage detection technique, which does not rely on any past baseline signals, is proposed to assess damage in composite plates by using an enhanced time reversal method. A time reversal concept of modern acoustics has been adapted to guided-wave propagation to improve the delectability of local defects in composite structures. In particular, wavelet-based signal processing techniques have been developed to enhance the time reversibility of Lamb waves in thin composite laminates. According to the time reversal concept, an input signal can be reconstructed at an excitation point (point A) if an output signal recorded at another point (point B) is reemitted to the original source point (point A) after being reversed in a time domain as shown in Figure 1. This process is referred to as the time reversibility of waves. This time reversibility is based on the spatial reciprocity and time-reversal invariance of linear wave equations. However, it should be noted that time reversal acoustic is originally developed for propagation of body waves in an infinite solid media. Additional issues such as the frequency dependency of time reversal operator and signal reflection due to limited boundary conditions should be addressed to successfully achieve the time reversibility for Lamb waves. By developing a unique combination of a narrowband excitation signal and wavelet-based signal processing techniques, the authors demonstrated that the original input waveform could be successfully reconstructed in a composite plate through the enhanced time reversal method (see Figure 2 (a)). However, this time reversibility of Lamb waves is violated when wave distortion due to wave scattering is caused by a defect along a direct wave path (see Figure 2 (b)). Examining the deviation of the reconstructed signal from the known initial input signal allows instantaneous identification of damage without requiring the baseline signal for comparison. The validity of the proposed method has been demonstrated through experimental studies of an anisotropic composite laminate structure with delamination.

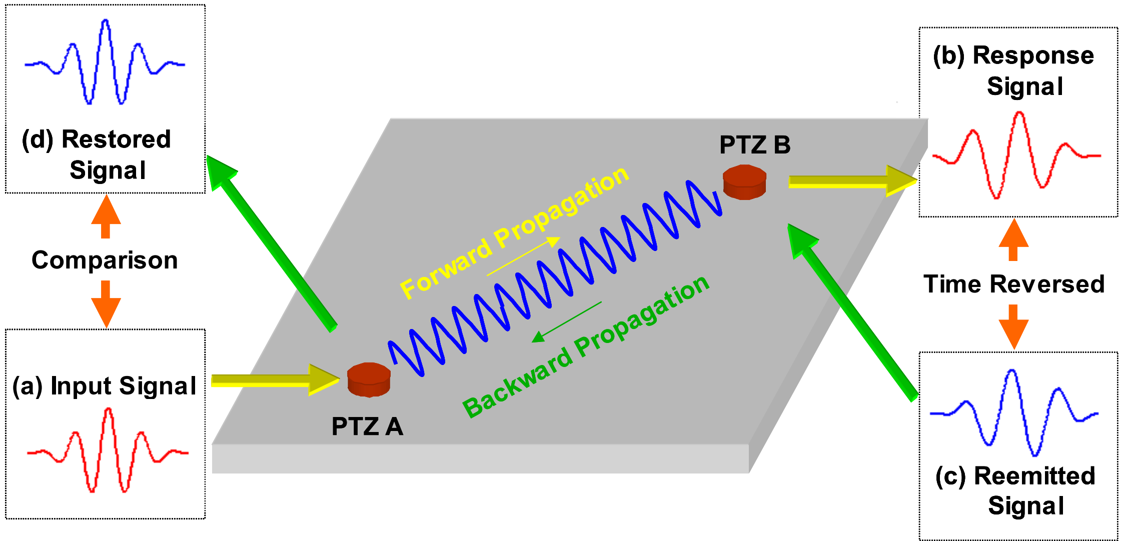
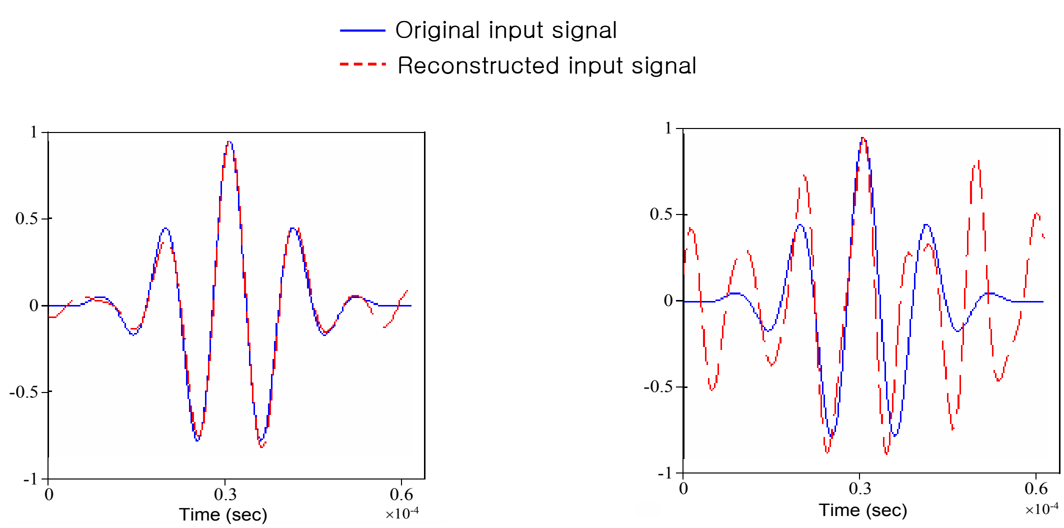


Figure 1: Schematic concepts of damage identification in a composite plate through time reversal processes.



(a) The time reversibility of Lamb waves for the intact composite plate

(b) The break-down of the time reversibility due to the internal delamination

Figure 2: Comparison between the original input signal (solid) and the restored signal (dotted) during the TRA process between actuating PZT # 6 and sending PZT #9