Development of an AE Waveform Simulation Method Using Experimentally Determined Sensor Responses

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KEYWORDS: *Acoustic emission (AE), Elastic wave simulation, 3D-FDTD, Piezoelectric sensor, Sensor response, Resonance*

An Acoustic emission (AE) is a nondestructive evaluation technique that detects transient elastic waves generated by crack initiation, propagation, friction, and other damage-related phenomena in materials and structures. Resonant AE sensors using piezoelectric elements are widely employed due to their high sensitivity; however, the detected waveforms are significantly distorted by resonance and the frequency-dependent response of the sensor, making direct comparison with simulated waveforms difficult. To address this issue, methods that experimentally characterize the sensor response and incorporate it into simulated AE waveforms have been investigated [1]. In AE measurements, the detected waveform W(t) can be expressed as

$$W(t) = S(t) * T(t) * R(t) \tag{1}$$

here $*$ denotes convolution, S(t) is the source waveform, T(t) represents wave propagation characteristics in the material, and R(t) is the sensor response. In contrast, 3D-FDTD simulations provide only S(t)$*$T(t), as they do not include the sensor response. Consequently, simulations alone cannot accurately reproduce experimentally measured waveforms. In this study, the sensor response R(t) was identified from experimental and simulated waveforms and incorporated into other simulated waveforms shown in Fig.1. As a result, the reproduced waveforms showed significantly improved agreement with experimental measurements compared with those obtained using simulation alone. Furthermore, regularization was introduced into the response identification process to stabilize the solution and enhance reproducibility. The proposed method demonstrated superior performance compared with conventional sensor response characterization approaches.

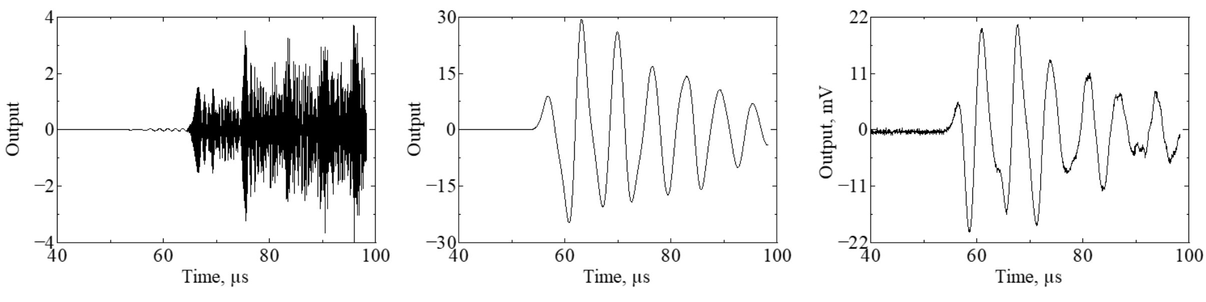

Figure 1. Comparison of waveforms obtained using different approaches: (left) 3D-FDTD simulation alone; (center) waveform reproduced using the proposed method; (right) waveform experimentally measured with a resonant AE sensor.

[1] K. Arakawa and T. Matsuo, “Acoustic Emission Pattern Recognition Method Utilizing Elastic Wave Simulation”, Materials Transactions, Vol. 58, No. 10 (2017), pp. 1411-1417.