Nonlinear ultrasonic modulation based failure warning for aluminum plates subject to fatigue loading

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PII: S0142-1123(18)30185-3
DOI: https://doi.org/10.1016/j.ijfatigue.2018.05.014
Reference: JIJF 4686

To appear in: *International Journal of Fatigue*

Received Date: 14 December 2017
Revised Date: 8 May 2018
Accepted Date: 10 May 2018

Please cite this article as: Kim, Y., Jin Lim, H., Sohn, H., Nonlinear ultrasonic modulation based failure warning for aluminum plates subject to fatigue loading, *International Journal of Fatigue* (2018), doi: https://doi.org/10.1016/j.ijfatigue.2018.05.014

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Abstract

This study presents an online fatigue crack failure warning system that can provide a warning of imminent failure of an aluminum plate structure with an initial notch when the plate is subject to constant-amplitude cyclic loading. For real-time warning, three piezoelectric transducers (PZT) are mounted on the surface of the structure for ultrasonic generation and sensing. Two sinusoidal input signals at distinct frequencies are applied respectively to two PZTs, and corresponding responses are measured by the third PZT. Ultrasonic waves cause crack closing and opening at the presence of a fatigue crack, and nonlinear ultrasonic modulation components appear at sum and difference of the input frequencies. The amplitudes of nonlinear ultrasonic modulation components initially increase as a fatigue crack grows. However, when the maximum stress intensity factor at the crack tip reaches the fracture toughness value of material, the modulation amplitudes suddenly decrease. The proposed failure warning system provides a failure warning by studying the patterns of measured nonlinear modulation components with respect to the fatigue crack growth. The performance of the proposed failure warning system is examined using aluminum plate specimens with various thicknesses and material properties.

Keywords: Structural health monitoring, fatigue crack, failure warning, nonlinear ultrasonic modulation, PZT transducer.