Advancements in Nonlinear Ultrasonic Evaluation of Weld Joints using FGW Mixing

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The phenomenon of feature-guided waves (FGWs), in which wave energy localizes around specific features like bends, stiffeners, and welds within plate-like structures, presents a valuable approach for defect detection in proximity to these features. While extensive research has examined the propagation of FGWs along features such as welded joints, much of it has relied on a linear response, yielding only amplitude and phase variations of the input signal. On the other hand, nonlinear ultrasonic methodologies have proven highly effective in delineating microstructural alterations in engineering materials at the early damage stage. In this paper, we employ a wave mixing approach to delve into the nonlinear response of FGWs as they propagate through a welded joint. We explore the nonlinear response of FGWs using a 3D time-step numerical simulation. The mutual interaction of the selected weld-guided mode pairs with wave mixing criteria, featuring distinct frequencies, results in the generation of second-order harmonic waves. The second-order harmonic generation induced by FGW mixing is successfully validated through experimental tests conducted on welded aluminum plates. The experimental results are well-matched with the theoretical and numerical analyses. Our study underscores the efficacy of FGW mixing as a valuable tool for assessing microstructural modifications within and around welded joints.