Synergizing High-Frequency Flexible Ultrasonic Arrays and Coded Excitation Schemes for Advanced Industrial Inspections

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High frequency (>15 MHz) ultrasound arrays have gained significant attention in recent years for their ability to provide higher resolution images providing higher sensitivity to smaller defects in materials and structures. This helps detecting defects at earlier growth stages as compared to lower frequency counterparts, preventing costly repairs or even catastrophic failures in some cases. However, the limited penetration depth of high-frequency sound waves can hinder the inspection of thicker components. Therefore, an advanced approach combining a high-frequency flexible ultrasonic array and coded excitation schemes to address the limitation in penetration depth, particularly of samples with intricate surface geometries, is presented. This investigation employed a novel 20-MHz 64-element 1 mm-pitch flexible linear array, developed by Novosound Ltd, using two different coded excitation schemes to improve the signal-to-noise ratio (SNR) and operability on planar and non-planar components. Linear chirps and Golay complimentary sequences were designed and employed with an arbitrary waveform generation tool to excite the array. Pulse compression was realised through the application of a matched filter, weighted by a Chebyshev window for Chirp excitation. An improvement verification study has been conducted with the array deployed on a 20 mm-thick planar aluminium sample and as anticipated, increase in SNR was observed as the length of the Golay codes increased, agreeing with a theoretical 3 dB improvement between successive length increments. Furthermore, the appropriate coded excitation scheme is contingent on the specific demands of the application, acceptable SNR, and the allowable length of dead zone that does not compromise the Fresnel zone performance. Moreover, an improvement of >17 dB in backwall reflection was detected when compared to a standard pulse excitation. The array offers the versatility to adapt to intricate surface profiles. A curved test specimen, representative of piping found in nuclear industry, was next explored in direct coupling using EchoPureTM couplant gel and through a 2-mm AqualeneTM rubber material. Both excitation strategies were systematically optimised and assessed for their defect detection capabilities across all experimental situations. The suggested approach, which integrates the flexible array with coded excitation strategies, has the potential to improve the quality of industrial inspections in terms of efficiency, accuracy, and reliability.