Exploiting Spatial Gradients in Laser-Induced Ultrasonic Wavefields for Defect Characterization

Zihan Wu[1], See Yen Chong[2], Michael Todd[2]

[1]Structural Engineering, University of California San Diego, USA, [1]Department of Structural Engineering, University of California San Diego, USA

Scanning laser-induced ultrasonic interrogation can lead to reconstruction of a spatially-dense wavefield from reciprocity considerations. This work exploits this spatial density to explore a damage imaging method. From the high spatial resolution data produced, a spatial gradient–based image processing technique was developed using gradient vectors derived from optical flow algorithms to extract features sensitive to defects. Localized mechanical impedance changes in the damaged area induce a local distortion of the waveform, which was quantified by the variation of the gradient vectors in the scanning area as time evolves. Such variation was accumulated over time with an analytically derived optimal statistical threshold filter to generate a both polar and circumferential gradients, and probability density functions in the uncertainty are derived. The proposed algorithm is shown to detect distinctive damage patterns when tested experimentally on a 3 mm aluminum plate with multiple simultaneous simulated defects. Compared to conventional techniques like local wavenumber estimation, the generation of the accumulated orientation map involves no filtering process in the frequency or wavenumber domain, but it comes at the expense of less accurate shaping of the defect. One advantage demonstrated is the ability to exploit the spatial covariance structure to classify defects as well as characterization beyond pure localization.