Nonlinear acoustic NDT and diagnostic imaging: waves vs vibrations

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For over than 60 years, nonlinear acoustics of solids conceived by its masterminds to be a delicate methodology of solid state physics has changed to a new applied technology for monitoring of deterioration in material properties and diagnostics of damage. The NDT application field now includes the nonlinear wave and nonlinear vibration modes. Both are based on the fact that material nonlinearity increases with decrease in intermolecular forces that makes nonlinear ultrasound a comfortable experimental instrument accompanied by a local rise of some nonlinear indicators (e.g. higher harmonics). A strong nonlinear response of weakly-bonded interfaces in adhesive bonds (down to kissing bonds) and planar defects, like cracks, delaminations introduces the nonlinearity localized in the defect area where the vibration nonlinearity steps up. Activated by a standing wave vibration version enables to probe the vibration nonlinear response over a total area of the specimen and is applicable to mapping and imaging of the faulty areas in large-size components. The concept of local defect resonance (LDR) combined with its nonlinearity identifies a nonlinear inclusion as a nonlinear oscillator and brings about qualitatively different dynamic and frequency scenarios (nonlinear and parametric resonances) in vibration nonlinear phenomena. Multiple nonlinear frequency components generated locally in a single scan enable to identify the defect position and size reliably and thus to increase the probability of defect detection. The LDR-induced trapping of the nonlinearity in the defect area has its pros and contras. On the one hand, it provides a defect-selective nonlinearity with feasibility for extremely efficient (even noncontact) nonlinear activation of damage. However, a direct acoustic read-out of the defect nonlinearity by the driving wave is barely possible and one ordinarily employs a laser vibrometer or a thermal camera instead. A low-cost alternative uses the resonant air-coupled emission (RACE) radiated by fractured defects as a footprint to locate and visualize the defects. It makes possible to apply commercial sonic/ultrasonic instrumentation for airborne activation and remote inspection of different materials and various scale components.