Measuring material nonlinearity with ultrasonic guided waves

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The microstructural features indicative of the early stages of material degradation represent a weak elastic nonlinearity that distorts ultrasonic waves, which can in-turn be measured from higher harmonics or combinational harmonics at sum or difference frequencies. The use of guided waves facilitates these measurements in plates because they do not require access to both sides of the plate and they can propagate long distances. At Penn State we have developed nonlinear measurement techniques based on the fundamental shear-horizontal wave mode being the primary waves that by self-interaction or mutual interaction generate secondary waves having lower amplitudes but are measurable with due care. The nondispersive nature of the fundamental shear-horizontal wave mode is very beneficial to these measurements. In addition, the selection of excitation frequencies and wave propagation directions needs to consider the power flux from the primary waves to the secondary waves. Moreover, the wave propagation characteristics, especially the wavestructure of the secondary waves, determine signal reception strategies. With all of the above considerations in mind, a number of possible measurement methodologies are highlighted, which include self-interaction as well as mutual interaction of co-directional primary waves and counter-propagating primary waves. Sample results are shown for reception from angle-beam, air-coupled, and bonded PVDF film receivers.