A Non-Collinear Mixing Technique to Measure the Acoustic Nonlinearity Parameter of Adhesive Bond from Only One Side of the Sample

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The acoustic nonlinearity parameter (ANLP) of a material is often positively correlated with the damage in the material. Therefore, the ability to nondestructively measure the ANLP may enable the nondestructive characterization of the material’s remaining strength. In this work, we developed a non-collinear mixing technique to measure the ANLP of adhesive bonds. One of the most significant features of the new method is that it requires only one-side access to the adhesive bond being measured, which significantly increases its utility in field measurements. Specifically, the test sample considered in this study consists of two aluminum plates adhesively joined together through a commercial adhesive tape. The non-collinear wave mixing technique consists of generating a longitudinal wave and a shear wave by piezoelectric transmitters attached to the same surface of the sample under test. These waves are introduced into the sample in such an angle that they will mix at the adhesive bond region. Mixing of these two waves generates a shear wave that propagates back towards the surface where the two waves were generated. This mixing wave is then recorded by a shear wave receiver placed on the same surface where the longitudinal and shear wave transmitters are located. It was shown that amplitude of this mixing wave is proportional to the ANLP of the adhesive bond.

To demonstrate the effectiveness of the newly developed technique, a freshly made adhesive sample was first measured using the non-collinear mixing technique to obtain the ANLP of the adhesive bond. This sample is then placed inside a thermal chamber for aging to change its ANLP. The sample was taken out of the thermal chamber periodically to measure its ANLP. The measured results clearly show that the ANLP varies with aging time. Initially, the ANLP decreases with aging time, possibly due to further curing. Afterward, the ANLP begins to increase with aging time, likely due to aging induced damage in the polymer adhesive. To verify that the signals received from the shear wave receiver are indeed the mixing wave, the finite element method was used to simulate the wave motion in the test sample. The simulation results clearly show that the signals recorded by the shear wave receiver are indeed the desired mixing wave, whose amplitude is proportional to the ANLP of the adhesive bond.