Waves propagating in anisotropic media are subject to skewing effects due to the media having directional wave speed dependence, which are characterized by slowness curves. Likewise, the generation of second harmonics is sensitive to micro-scale damage that is generally not detectable from linear features of ultrasonic waves. Here, the effect of skew angle on second harmonic guided wave measurement in a transversely isotropic lamina and a quasi-isotropic laminate are studied numerically. The strain energy density function for a nonlinear transversely isotropic material is formulated in terms of the Green-Lagrange strain invariants. The guided wave mode pairs for cumulative second harmonic generation in the plate are selected in accordance with the internal resonance criteria – i.e., phase matching and non-zero power flux [1,2] – based on the plain strain condition. Moreover, the skew angle dispersion curves for the mode pairs are obtained from the semi-analytical finite element method using the derivative of the slowness curve. The skew angles of the primary and secondary wave modes are calculated for the principal propagation directions and wave propagation simulations are carried out using COMSOL. The cumulative second harmonic generation is analyzed along the wave propagation directions accordingly. The importance of skew angles on the cumulative second harmonic generation and the mode selection criteria is shown for both a unidirectional lamina and quasi-isotropic laminates.

References: