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Investigating Coupled Flexural Mode Behavior Observed in NRUS Testing

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Nonlinear resonant ultrasound spectroscopy (NRUS) is typically performed using unidirectional testing methods where one type of mode is considered in the analysis. The mode types considered are longitudinal, torsional, or flexural modes, and the response is measured at a single location. In our experimental work, we have observed coupling behavior between longitudinal and flexural modes when exciting a Berea sandstone rod in the longitudinal direction.

The sandstone rod is excited with a piezo (PZT) ceramic disc at one end and measured using a 3D laser doppler vibrometer (LDV) along the top in the longitudinal direction, as shown in Figure 1a. Due to multidirectional displacement of the PZT, flexural modes are excited in addition to longitudinal modes. We measure the flexural modes in the transverse (Z) direction response FFT, shown in Figure 1b. While exciting in the longitudinal direction, the longitudinal modes exhibit nonlinear softening, but the bending modes exhibit nonlinear hardening. Due to the nonlinearity of sandstone, we expect coupled modes, but we will attempt to better understand the coupling.

We aim to study the behavior by predominately exciting the sandstone rod in each mode type, torsion, longitudinal, and flexural separately and seeing if the behavior shown in Figure 1b remains. Through the comparison, we will study if the coupling of the mode types provides better understanding of the overall nonlinear behavior of the material.

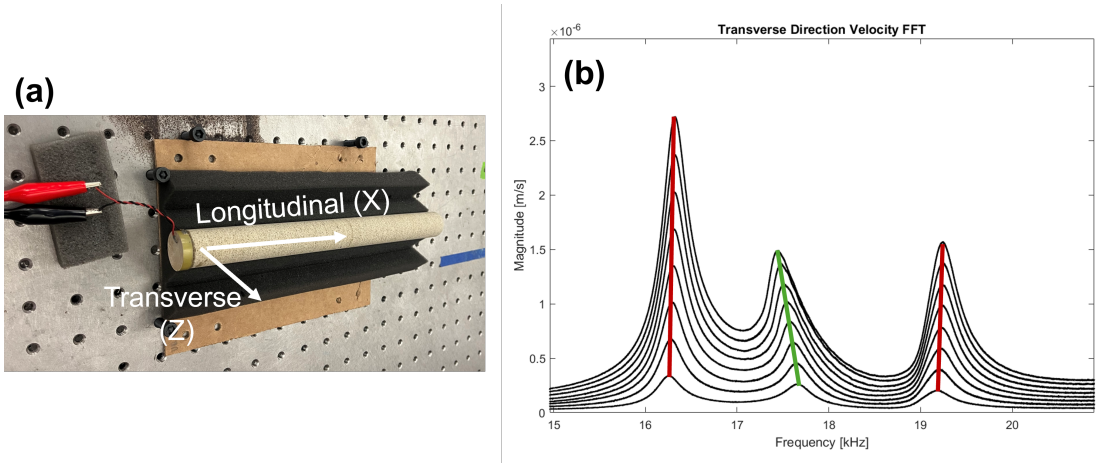

Figure 1: Figure 1. Exciting the Berea sandstone longitudinally (X direction) and (a) measuring with a 3D LDV in the transverse (Z) direction yields (b) hardening of bending modes (red) and softening of the longitudinal mode (green).

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