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Fast and slow dynamic effects in Nonlinear Resonant Ultrasound Spectroscopy

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Nonlinear Resonant Ultrasound Spectroscopy (NRUS) is a fundamental technique for assessing elastic nonlinearity in materials, particularly those exhibiting elastic hysteresis. Such materials are also known to exhibit fast and slow dynamic response, which is evolving in time. In this study, we examine the interplay between slow and fast dynamic effects in NRUS measurements performed on a sandstone rectangular beam excited at its first longitudinal mode.

To that purpose, we used Dynamic Acousto-Elastic Testing (DAET) to monitor velocity variations at the specimen's center during a complete run of NRUS probing. NRUS measurements were conducted using sine-train signals sweeping across resonance peaks while alternating between high and baseline amplitudes to facilitate "instantaneous" baseline tracking. The results confirm that the NRUS probing creates a sequence of conditioning and relaxation events, which, in part, accumulate during the run of the experiment. This effect is responsible for possible variation of NRUS curves depending on measurement procedure and for observed "hysteresis"when increasing and decreasing branches of NRUS curves are compared.

A theoretical model is proposed to describe these effects, attributing them to material defects relaxing at different time scales. It achieves a qualitative agreement with experimental results, using solely multi-relaxation components. As a consequence, material characterization methods should be updated to consider these effects, including the definition of quantitative material parameters, as current methods are, to some extent, subject to systematic error, due to cumulative effects.

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