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Evaluation of Plasticity-Induced Elastic Nonlinearity in Steel Using Nonlinear Guided Waves

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Non-destructively monitoring plasticity-induced microstructural changes in metals can provide valuable insights into structural integrity and enable early failure detection. Conventional ultrasonic methods often lack the sensitivity to detect such early-stage changes. Nonlinear ultrasonic techniques, particularly second harmonic generation using guided waves, offer enhanced sensitivity, making them well-suited for tracking microstructural evolution and identifying precursors of damage . In this study, we investigate the use of second harmonic generation of guided waves to evaluate elastic nonlinearity in steel subjected to progressive plastic deformation. A uniaxial tensile test is used to introduce homogenous microstructural changes within the gauge length of a plate type dog bone 304 steel specimen. Internally resonant guided wave mode pairs (S1–S2 and S2–S4) are excited and received at multiple locations within the gauge length to capture the cumulative effect of second harmonic amplitude. We will present the measured relative acoustic nonlinearity, β', across different plastic strain levels and highlight trends observed in the second harmonic amplitude. The results will be discussed in the context of the sensitivity of second harmonic generation to evolving microstructure. This study will evaluate the feasibility of using guided wave second harmonic generation for detecting plasticity-driven changes in 304 steel and outline its potential for nondestructive material characterization.

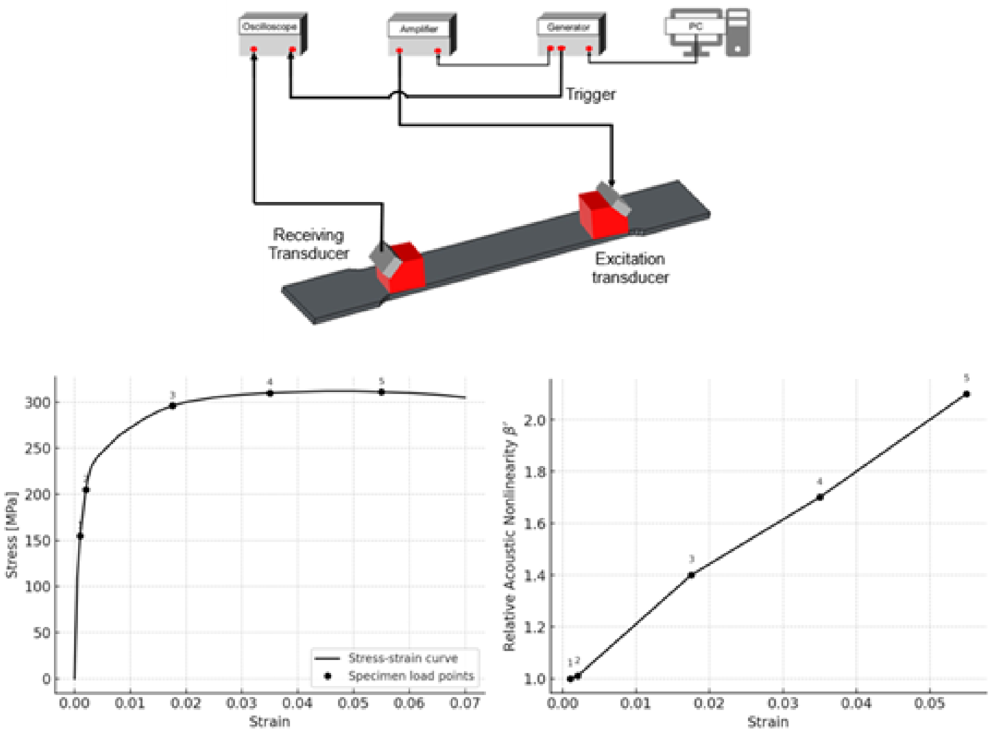

Figure 1: (a) Experimental setup for Guided wave testing on 304 steel dog bone samples (b) Specimen load points in the elastic and plastic zones on the stress strain curve (c) Expected results of Acoustic Nonlinearity β at different strain levels

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