ABSTRACT OF PRESENTED PAPER

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EXPERIMENTAL OBSERVATION OF CUMULATIVE SECOND HARMONIC GENERATION OF LAMB WAVE MODES

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Abstract: Non-linear Lamb waves have been employed in recent years to monitor microstructural changes in thin-walled metallic plate and shell structures. The extreme sensitivity of this technique is advantageous for detection, but also leads to high variability in measurements taken. The measurement of the material nonlinearity is complicated by several factors, such as the nonlinearity present in measurement equipment, transducer position and angle, as well as the coupling conditions at the transducer-specimen interface. The present article reports experimental results obtained for the inherent material nonlinearity in a large undamaged and unloaded Aluminium plate. The need for improved robustness of the experimental procedure is identified.

1. Introduction

Higher harmonic generation (HHG) is a nonlinear ultrasonic technique capable of detecting and monitoring microstructural changes in metals prior to macroscopic damage and/or microcracking [1]. The physical mechanism involves the distortion of an ultrasonic wave of a given frequency as it interacts with the microstructure of the medium, resulting in the transfer of energy from the excitation frequency to higher harmonics, which occur at multiples of the original frequency. HHG measurement methods have received significant focus and attention in the literature in recent decades since measurements can be made utilising commercial transducers and standard ultrasonic testing equipment [1].

While most studies on the acoustic harmonic generation deal with nondispersive modes such as bulk and Rayleigh waves, the corresponding phenomenon in dispersive guided waves, such as Lamb waves in a plate, is also of great interest, since guided waves can propagate up to large distances without attenuation. One of the practical applications of nonlinear Lamb waves is in monitoring early-stage fatigue damage in critical thin-walled structures, for example, aircrafts and pipelines. In order to measure the nonlinear effect with sufficient signal to noise ratio, it is necessary that the conditions of internal resonance are met. These conditions are: the primary mode and its harmonic mode must have identical phase and group velocities and there must be non-zero power flux from primary to second (or higher) harmonic mode [2]. Under the conditions of internal resonance, the amplitudes of the primary mode and harmonic mode, A_1 and A_n, are related according to [3]:

$$\frac{A_n}{A_1^2} = \kappa_n x,$$

where x represents the propagation distance from a cylindrical source and κ_n is the rate of accumulation of the nth harmonic. This rate depends on the material's properties, wave mode and strength of nonlinearities [3].

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2. Results

The wedge technique was used to generate and detect symmetric mode pairs S1 and S2 in a large 1.2×1.2 m Aluminium 6061 T6 plate of thickness h = 1.6 mm. A high-power-gated amplifier (RITEC RAM-5000 Mark IV) was used to generate a tonal burst at 2.25 MHz. A Hanning window was applied with 20 cycles and 0 degrees phase angle and the input voltage was set at 1000 V_{pp}. The signal was fed into a narrowband transducer (Panametrics X-1055) with a center frequency of 2.25 MHz and received by a narrowband transducer (Panametrics A-405S) with a center frequency of 5 MHz. Acrylic wedges with angle $\theta = 25.6°$ were used at both ends to promote the excitation and detection of the S1-S2 mode pair only. The experimental setup is shown in Figure 1a. The short-time Fourier transformation technique was used to extract the amplitudes of the primary mode and second harmonic from the time-domain signal recorded by the receiving transducer.

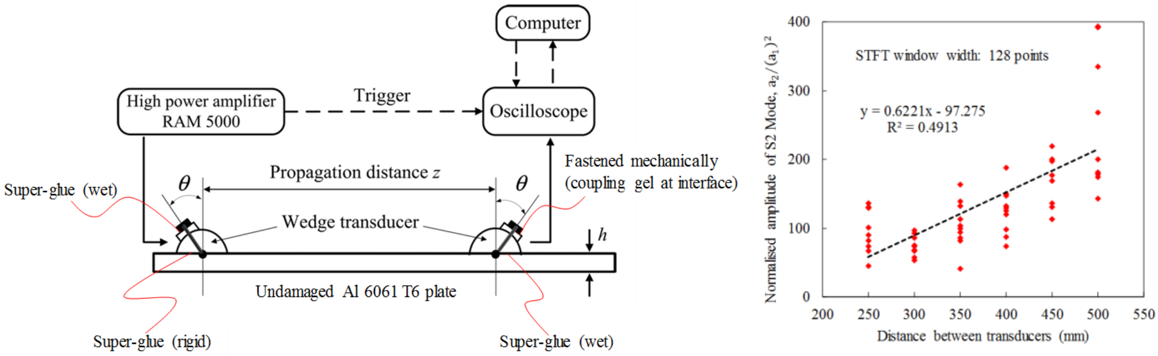

Figure 1. (a) Schematic diagram of the experiment and (b) growth of the second harmonic with increasing propagation distance.

In Figure 1b, the experimental obtained dependence of the normalised amplitude of the second harmonic, A_2/A_1^2 on the propagation distance, x is fitted against the theoretical linear relationship. Although a satisfactory fit is obtained, a large scatter is observed in the experimental measurements. Since the same specimen, measurement equipment and signal processing parameters were used throughout the experiment, the scatter can be attributed to the coupling between the transducers and the specimen. The robustness of the current approach can be improved by using coupling fixtures which provide accurate placement of the transducers on the plate and a constant clamping force.

3. Conclusions

In this paper we presented the outcomes of an experimental program, which was aimed on the investigation of the cumulative second harmonic generation in a metallic plate. It was verified that the amplitude of the second harmonic increases linearly with the distance from the source of the nonlinear Lamb waves. However, a major limitation of the experimental results obtained so far is the repeatability of the measurement. The use of non-contact measurement techniques at the receiving end, such as air coupled transducers or laser interferometer could improve the robustness of the experimental technique.

References

[1] K.H. Matlack, J.-Y. Kim, L.J. Jacobs and J. Qu. Review of Second Harmonic Generation Measurement Techniques for Material State Determination in Metals, *J. Nondestruct. Eval.* 2015;34:273.

[2] N. Matsuda and S. Biwa. Phase and group velocity matching for cumulative harmonic generation in Lamb waves, *J. Appl. Phys.* 2011;109;094903.

[3] K.H. Matlack, J.-Y. Kim, L.J. Jacobs and J. Qu. Experimental characterization of efficient second harmonic generation of Lamb wave modes in a nonlinear elastic isotropic plate, *J. Appl. Phys.* 2011;109;014905.