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NONLINEAR NONDESTRUCTIVE EVALUATION TECHNIQUE IN SOLID MATERIAL

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ABSTRACT

Feasibility of Nonlinear Acoustic Modulation (NAM) technique [J.P. Kim et al., J. Acoust. Soc. Am. 101(5), pp. 3029-3030, 1997] is discussed for nondestructive defect evaluation. NAM technique is applied to localize a defect in a steel rod, and also extended to 2-dimensional defect evaluation in a layered structure with two glass plates. The experimental results show that the second harmonic method can easily indicate the existence of tiny defects in both one and two-dimensional structures. NAM technique with time-delay measurements can also accurately locate the defect in the steel rod.

1 - INTRODUCTION

It is very critical to judge whether there is a defect in solid materials for composite structures such as airplanes, nuclear reactors, and bridges. However, conventional nondestructive evaluation methods experience difficulties to detect tiny defects or cracks in such materials. One of the commonly used acoustic nondestructive evaluation methods is the pulse-echo method. Such a linear acoustic method has many difficulties to distinguish the signals of tiny defects or cracks from the multi-reflected or modulated ones except very simple cases.

When defects exist in a solid material, nonlinear acoustic responses become more dominant and can be easily utilized for defect detection [1,2]. Feasibility of nondestructive NAM technique for flaw detection is discussed for a solid steel rod as a 1-dimensional (1-D) structure and also for a set of glass plates as a 2-dimensional (2-D) layered structure. In the 2-D glass-plate structure the air coupling between the plates is considered as a defect while the water coupling is for the defect-free controlled case.

2 - NONLINEAR ACOUSTIC MODULATION METHOD IN A 1-D STEEL ROD

The experimental setup is shown for NAM feasibility tests of 1-D steel rod and 2-D glass-plate layered structures in Fig. 1, respectively.

As a 1-D specimen a steel rod of diameter 1.3 cm and length 150 cm was chosen. An artificial defect induced by hammering was identified in the specimen with an optical microscope. The measured sound speed in the steel rod was 4575 m/s. The variation of second harmonic power spectrum level of an incident wave of 98 kHz was observed for defect evaluation. The frequency spectra of scattered signals in the defect-free and defective steel rods were shown in Fig. 2, respectively. The second harmonic spectrum level in the defect-free rod was masked by background noise. Its level for the defective rod was 15 dB higher than that for the defect-free one.

The sum and difference frequency components due to the frequency modulation of two different incident waves of 98 kHz and 206 kHz were also investigated for localizing a defect in the steel rod. The sum and difference frequency components became dominant in the defective rod while they were masked with the background noise in the defect-free rod. The second harmonic spectrum levels for the defective rod were ~23 dB higher than those for the defect-free one. These experimental results show that the existence of defects is easily examined with observation of the second harmonic generation and the frequency modulation of incident waves.

NAM technique with time-delay measurements was also used to locate a defect. As shown in Fig. 1 the defect is located at 40 cm from the high frequency transmitter and at 20 cm from the receiving sensor. With the total traveling distance 60 cm and the sound speed 4575 m/s, the total estimated traveling

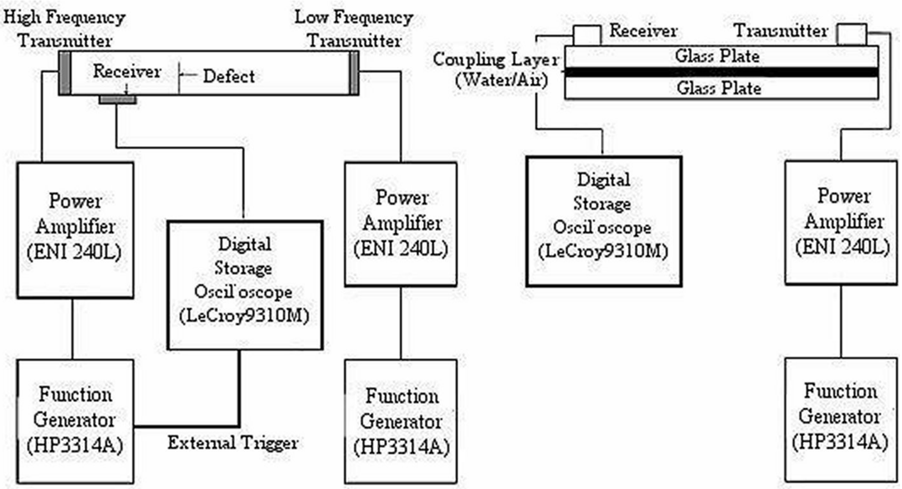
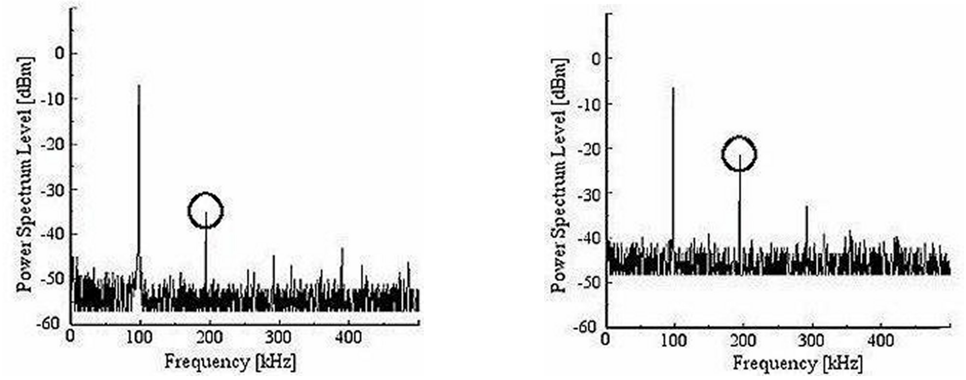


Figure 1: Experiment setup for NAM technique.



(a): Defect-free steel rod. **(b):** Defective steel rod.

Figure 2: Second harmonic frequency spectra for 1-D steel rods.

time is 131 μs in the steel rod. Figure 3 also shows that the frequency-modulated signals appear well at 130 μs.

3 - SECOND HARMONIC METHOD IN 2-D GLASS-PLATE LAYERS

The second harmonic method is extended for two glass-plates as a two-dimensional (2-D) layered structure. The setup is shown in Fig. 1 (b). In the 2-D structure air coupling between the plates is considered as a defect while water coupling is the defect-free controlled case. Each glass plate has the dimension of $248\times297\times5$ mm^3.

The second harmonic modes were investigated in the scattered waves from the coupling layer between the glass plates. Thickness resonance modes of glass plates were excluded. The power spectrum level of second harmonic mode for air coupling is 15 dB higher than for that for water coupling.

4 - CONCLUSION

Nonlinear acoustic modulation (NAM) technique for nondestructive flaw detection is discussed for a solid steel rod as a one-dimensional (1-D) structure and also for a set of glass plates as a two-dimensional (2-D) layered structure. NAM technique with time-delay measurements can accurately locate a defect in the 1-D steel rod. The second harmonic method is also very feasible to evaluate a tiny defect in the 2-D layered structure as well as the 1-D rod structure.

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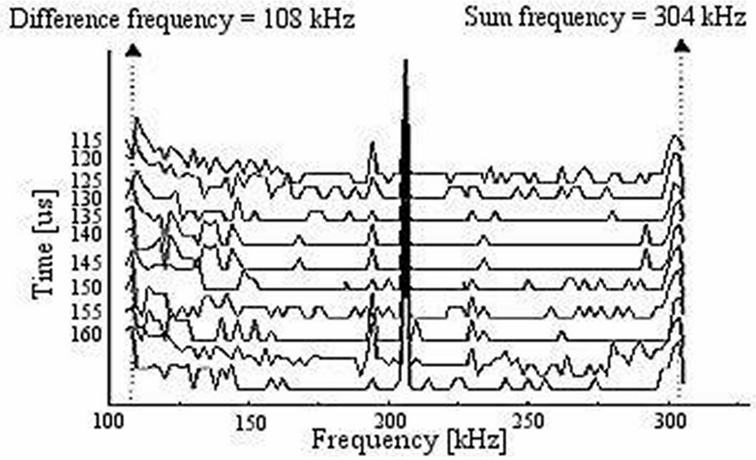
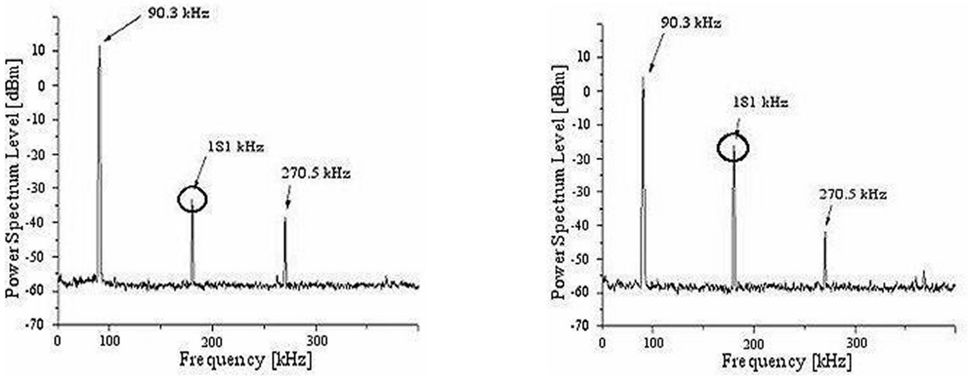


Figure 3: Frequency spectra of time-delay measurements in a steel rod.



(a): Water coupling. **(b):** Air coupling.

Figure 4: Second harmonic frequency spectra for a 2-D glass-plate layer structure.

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