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A METHOD FOR ACCURATE MEASUREMENT OF SHEAR WAVE ATTENUATION COEFFICIENT USING A CONTACT TRANSDUCER

Guangdong Zhang, Shuzeng Zhang[1], Xiongbing Li
School of Traffic and Transportation Engineering,
Central South University
Changsha, China

Ping Hu
Affiliation Here
Wuhan, China

ABSTRACT

Accurate measurements of the ultrasonic shear wave attenuation coefficient are essential for the quantitative nondestructive evaluation of the microstructure of a material. This work provides an experimental technique for measuring this coefficient using a contact method. The first and second pulse-echo shear wave signals are measured and are used to calculate the frequency-dependent attenuation coefficient; in this process, the diffraction and the diffraction-affected partial reflection coefficient are corrected to improve the accuracy of measurement. The diffraction coefficient is calculated from measurements of the shear wave velocity, and the partial reflection coefficient is determined experimentally by using another transducer on the opposite side and taking into account for wave diffraction effects. The shear wave attenuation coefficient is determined for samples of different thicknesses, and these results show good agreement over a broadband frequency, thus validating the proposed method.

Keywords: shear wave attenuation coefficient, contact pulse-echo method, partial reflection coefficient, diffraction correction

1. INTRODUCTION

Ultrasonic shear wave attenuation coefficient is sensitive to the microstructure of a material, and has been widely used in the nondestructive evaluation of material properties such as hardness, grain size, porosity and fatigue [1-3]. However, the partial reflection between a sample and the transducer can has a great effect on the measurements of this attenuation when using a contact pulse-echo method. Considering the partial reflection coefficient at the interface, a reasonable correction scheme for the attenuation coefficient is developed. The proposed method provides an effective nondestructive tool for accurate measuring the shear wave attenuation coefficient of a material.

2. MATERIALS AND METHODS

The contact pulse-echo experimental setup is shown in Fig. 1, which illustrates the ultrasonic shear wave circular transducers and samples with different thicknesses used here. Two main experimental steps are needed to measure the attenuation coefficient. Using the measurement of a sample of thickness z as an example, these steps are as follows:

Step 1: Measure the first and second pulse-echo wave signals using a sample of thickness z. The shear wave velocity can be determined using the time of flight method, and the diffraction corrections can then be calculated.

Step 2: Measure the first pulse-echo wave signal using a sample of thickness 2z, and then couple a similar shear transducer on the other side to measure this wave signal again. The partial reflection coefficient of the sample of thickness 2z is then calculated. Both diffraction and partial reflection are corrected to determine the attenuation coefficient of the sample of thickness z.

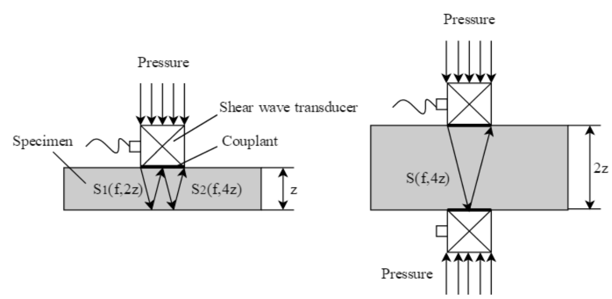

Fig. 1. Two-step experimental process for measuring the attenuation coefficient using contact shear wave transducer.

The expression for determining the attenuation coefficient of shear waves due to material microstructures can be derived as:

$$\alpha_f = \frac{1}{2z}\left[\ln\left(\frac{S_1(f,2z)}{S_2(f,4z)}\right) + \ln\left(\frac{D(f,4z)}{D(f,2z)}\right) + \ln\left(\left|R_T\left(f,2z\right)\right|\right)\right] \quad (1)$$

Through Eqs. (1), the attenuation coefficient of the shear waves can be accurately measured. Experiment results validating the proposed method are reported in the following section.

[1] Contact author: sz_zhang@csu.edu.cn

3. RESULTS AND DISCUSSION

The partial reflection results obtained using the samples of thickness 20 and 40 mm are shown in Fig. 2. The magnitudes and distributions in the frequency domain are different from each other, and this demonstrates that the diffraction has a significant effect on the partial reflection coefficients.

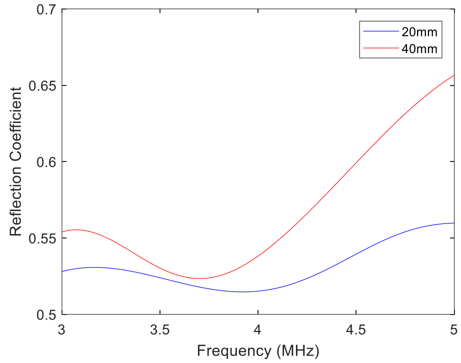

Fig. 2. Diffraction-affected partial reflection coefficients for samples with thickness 20 and 40 mm.

When the diffraction and partial reflection coefficients are corrected, the measured attenuation coefficients of shear waves in aluminum samples of thickness 10 and 20 mm are shown in Fig. 3. The results when the partial reflection effects are neglected are also shown in the same figure for comparison. It is observed that when only the diffraction corrections are applied to samples of different thicknesses, the measured attenuation coefficients are different; however, when the partial reflection effects have been corrected, the deviation of the attenuation in the two samples is significantly reduced.

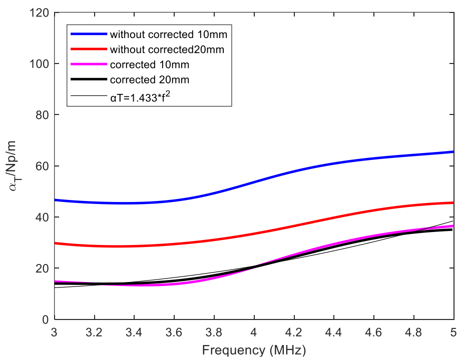

Fig. 2. Results for the measured ultrasonic shear wave attenuation coefficients.

4. CONCLUSION

1) This work presents a pulse-echo contact method for measuring the absolute attenuation coefficient of shear waves with corrections of the diffraction and diffraction-affected partial reflection.

2) An experimental method is developed for measuring the partial reflection coefficient, and the results show that coefficients measured using samples of different thicknesses vary a great deal.

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