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DETERMINATION OF TRANSMISSION SPECTRA USING ULTRASONIC NDE

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ABSTRACT

Reliable inversion of elastic properties of materials from ultrasonic wave propagation data is an attractive non-destructive characterisation method requiring good quality ultrasonic transmission data. This paper discusses the goniometry-based through transmission experiments on plate samples of various thicknesses using a wide-aperture PVDF receiver that provides good quality transmission data over a wide range of angles. This was verified with metal and composite samples. The dispersive characteristics, evaluated from the measured transmission data, were verified by comparing with the theoretical dispersion curves for the samples. A good correlation was found between the theoretical predictions and experimental results on using a wide-aperture receiver.

Keywords: Goniometry; ultrasonic transmission spectra; material characterisation; wide-aperture transducer; dispersion.

1. INTRODUCTION

Multi-layered composite materials are currently finding increasing engineering applications. In addition to high strength to weight ratio, composites offer flexibility to designers in achieving the required strength and stiffness by tailoring the stacking sequence and layer thicknesses. However, composites are very sensitive to their manufacturing processes, service conditions and the natural environment, either one or all of which may induce defects resulting in a serious degradation in their load carrying capacity [1]. With the extensive use of a variety of composites, which exhibit different degrees of anisotropy, accurate testing of these materials in a nondestructive manner has become indispensable. Testing here includes characterization of the material elastic properties, detection of defects in terms of material deterioration and identification of laminate disbonding. Ultrasonic techniques have been found to be extremely successful for these applications, since the stress waves interact directly with the material elasticity. The variability in the properties of multi-layered composites makes their characterisation an essential process [2].

In experimental determination of elastic constants, ultrasonic transmission coefficients are frequently used, as it does not require a signal separation like a bulk-wave transit-time method [3]. Another method found in the literature is based on time of flight measurement of the wave propagation in the material under inspection [4]. The plane-wave transmitted acoustic field is the frequency spectrum of the acoustic field transmitted by the plate when it is insonified by an incident plane wave. If one divides the transmitted acoustic field by the incident plane wave spectrum then one obtains the transmission coefficient. In order to determine the elastic constants from the transmission spectra, the transmission data obtained must be perfect. The general methodology adopted in measurement is to use a goniometry based ultrasonic immersion set-up [5].

2. EXPERIMENTAL SET-UP

Schematic of the goniometry based immersion set-up used for experimentation is shown in Figure 1. Shashidhara et. al. [4] have used a similar set-up for time of flight-based measurements. The sample plate to be tested was held on an indexing holder between an ultrasonic transmitter and a receiver. The whole arrangement is immersed in water.

3. EXPERIMENTAL RESULTS

The initial experiments were conducted on Aluminum plate samples of 2 mm, 4.67 mm, 10.3 mm and 12.5 mm thicknesses using conventional ultrasonic immersion transmitter and receiver. The experimental results for a 2 mm thick aluminum plate is shown in Figure 2. The experimental transmission spectra match closely to the theoretical spectra, which has the features of dispersion curves.

Similar result on 6.5 mm Aluminum sample is shown in Figure 3.

It can be clearly seen from Figure 3 that the theoretical and experimental transmission spectra differ significantly after the first critical angle. This can be attributed to the inability of the conventional receiver in collecting the laterally shifted signals beyond the first critical angle in case of thick samples.

In order to ascertain whether the problem can be rectified by the use of a large area receiver, experiments were carried out by giving a transverse movement equal to the dimension of the receiver element and the signals collected at various angles for each position of the receiver were added. The improvement in spectra obtained by this confirmed that the use of a wide aperture transducer would solve the problem. A commercially available Polyvinylidene fluoride (PVDF) transducer (156 mm by 18 mm) was chosen as a single large area receiver for further experimentation. The PVDF film was mounted on a specially designed fixture that made it to stay firm. The PVDF's have a wide spectrum of reception and transmission. This gave additional advantage in the use of same receiver along with various transmitter frequencies. The results from measurements on various samples with PVDF as receiver and conventional transmitter are shown in Figure 4. These clearly show the advantage on using PVDF as receiver.

Experiments were carried out on Graphite-epoxy composite samples of different thicknesses. The transmission spectra for a 2 mm thick unidirectional Graphite-Epoxy composite is shown in Figure 5.

4. CONCLUSIONS

The use of large area planar receiver (PVDF) has been shown to collect laterally shifted signals efficiently. The PVDF's are cheaper compared to the conventional ultrasonic transducers in addition to having a larger aperture and a wide spectrum of reception and transmission. It has also been shown that good transmission spectra, essential for determining elastic constants through inversion, could be obtained for a wide range of angles using PVDF.

5. REFERENCES

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FIGURES

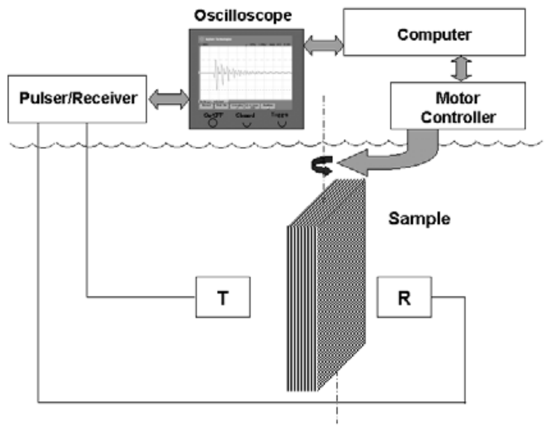

Figure 1. Schematic of the Goniometric based experimentation set-up

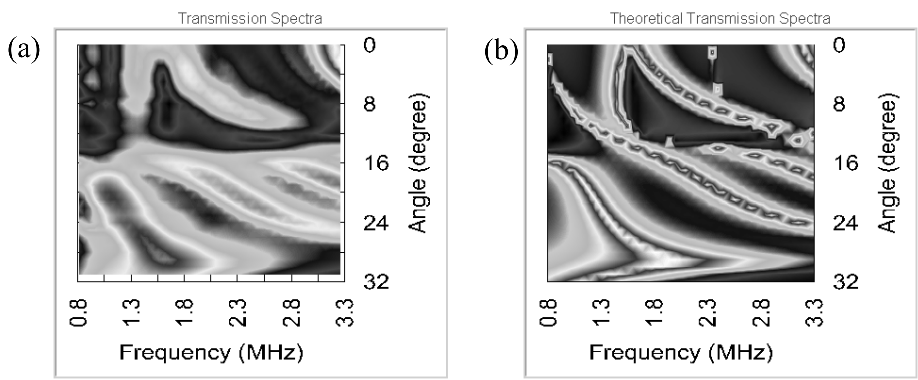

Figure 2.Transmission spectra for a 2 mm thick aluminum plate (a) Experiment using conventional ultrasonic transmitter and receiver (b) theoretical.

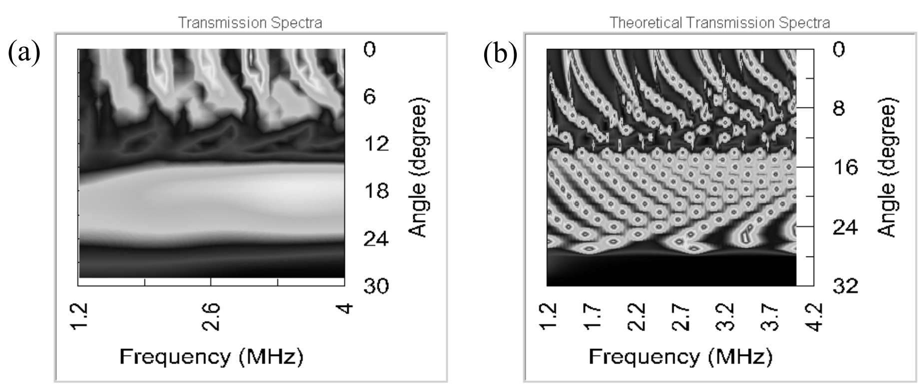

Figure 3. Transmission spectra for a 6.5 mm thick aluminum plate (a) Experiment using conventional ultrasonic transmitter and receiver (b) theoretical.

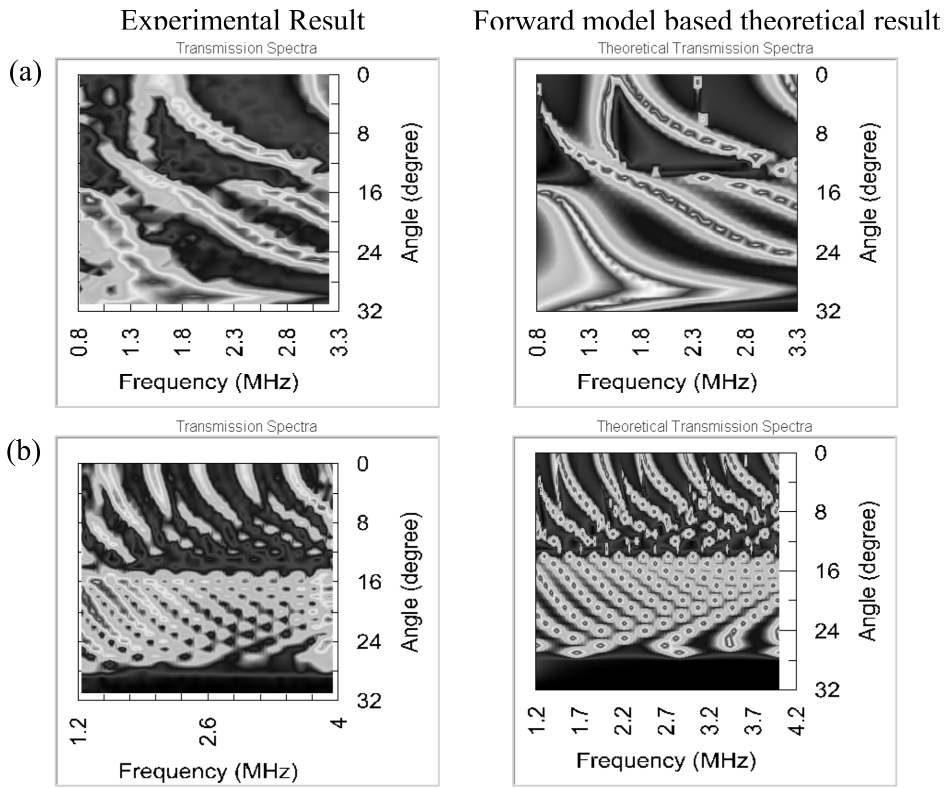

Figure 4 Transmission spectra for Aluminum plate of (a) 2 mm thickness, (b) 6.5 mm thickness.

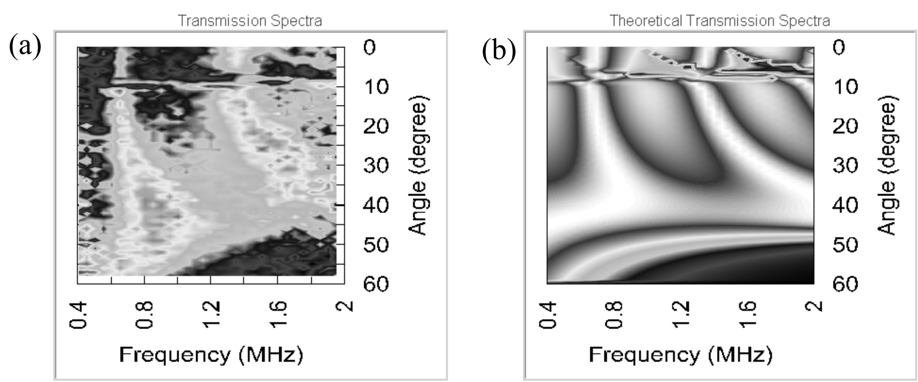

Figure 5. Transmission spectra for a 2 mm thick Graphite Epoxy plate (a) Experiment using conventional ultrasonic transmitter and PVDF receiver (b) theoretical.