Development of novel air-coupled ultrasonic methods for investigation of properties of sheet composite structures

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1. Introduction

Ultrasonic non-destructive testing techniques (NDT) based on application of guided waves are already used for inspection of plate - type structures made of various materials including composite materials. Applicability of such methods may be widened by employing air-coupled techniques (1). The main currently encountered problem is big losses of ultrasonic signals caused by the attenuation and significant mismatch of acoustic impedances of ultrasonic transducers and air. The objective of this work is to develop novel air-coupled ultrasonic techniques based on excitation of guided waves by means of improved ultrasonic arrays and to apply them for a non-destructive evaluation of the properties of sheet type composite and polymeric structures.

2. Experimental investigation

For excitation of guided waves in composite plates and polymer films an air-coupled phased linear array was employed. For this purpose a novel air-coupled array with PMN-32%PT piezoelectric crystals were developed (2). In order to reduce losses due to attenuation low frequency (<50 kHz) ultrasonic signals were selected. For transmission and reception of ultrasonic signals in such frequency range strip-like piezoelectric elements vibrating in a transverse extension mode were used. The good performance of the array is obtained due to a high electromechanical coupling coefficient which for the transverse extension mode is $k_{32} > (0.84 – 0.90)$.
The possibility to excite guided waves in a viscoelastic thin plate was checked using the experimental set-up shown in Figure 1. For experiments, a thin plate of 0.15 mm thickness made of polyethylene terephthalate (PET) was selected. The air-coupled linear 8-element array was excited by a 39.4 kHz and 3 periods electric burst. The ultrasonic wave transmitted via the air gap between the array and the PET film excited the antisymmetric A_0 mode Lamb wave in the film. This mode is very dispersive but selecting the operation frequency and adjusting delays of the excitation signals it is possible to excite efficiently a pure A_0 mode. The normal displacements caused by this mode were recorded by the OFV-5000 (Polytec) laser interferometer. The mechanical displacements at the point located L=1 mm from the last element of the array are shown in Figure 2. The measured phase velocity in this film at the frequency 39.4 kHz was v=135 m/s what is very close to the calculated ultrasound velocity be the semi- analytic finite element method. The experiments show possibility to excite with the proposed air-coupled array a slow ultrasonic A_0 wave in plates, e.g. when the phase velocity of those waves is slower than the ultrasound velocity in air. In this case there are no losses due to a wave leaking to air, that allows covering longer distances for NDT.

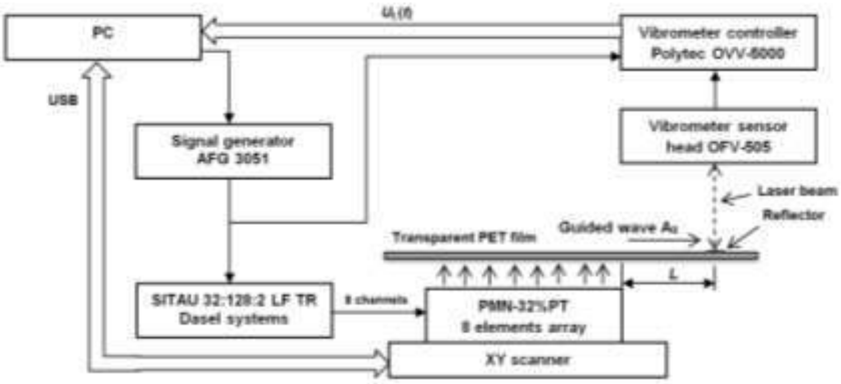

Figure 1. Experimental set-up for investigation of guided waves

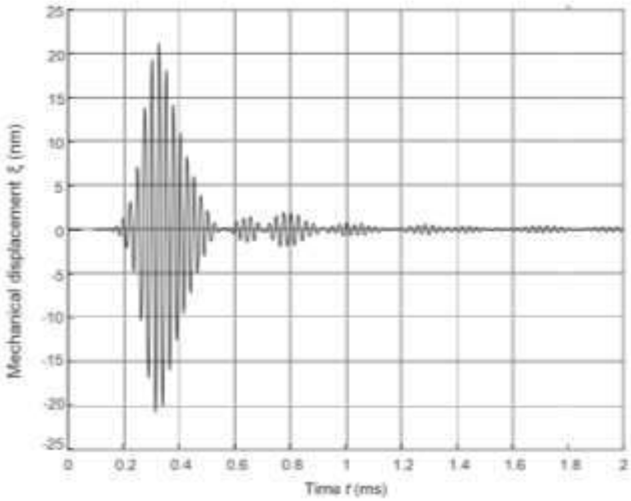

Figure 2. Waveform of A_0 mode normal displacements in PET film

3. Conclusions

Experimental investigation of air-coupled excitation of guided waves in CFRP plates and polymeric films by the developed array was performed. It was shown that by employing the proposed excitation and reception algorithms it is possible to generate various guided waves including waves with the velocity slower than the velocity of ultrasonic waves in air. It opens new possibilities for NDT of composite structures.

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References and footnotes

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